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RADIOLOGICAL HEALTH HANDBOOK. REVISED EDITION

Consumer Protection and Environmental
Health Service
Rockville, Maryland

January 1970

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RADIOLOGICAL HEALTH HANDBOOK

Compiled and edited
by the
Bureau of Radiological Health
and the
Training Institute
Environmental Control Administration

Revised Edition
January 1970

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Consumer Protection and Environmental Health Service
Rockville, Maryland 20852

[redacted]

FOREWORD

Twenty years ago the Public Health Service developed the first Radiological Health Handbook as a training aid, and it has since become a basic reference and a major resource for professional personnel and students in the field of radiological health. Credit for the development of the Handbook goes to members of the radiological health training staff, who through the years compiled and revised the information and data included in the book.

New knowledge, new technological advancements, and the enactment of Public Law 90-602, "Radiation Control for Health and Safety Act of 1968," made the last edition outdated and inadequate. In 1968, Mr. James G. Terrill, Jr., then Director, National Center for Radiological Health, initiated revision of the Handbook. Suggestions for additions, corrections, and deletions were obtained from Handbook users across the United States and in a number of foreign countries. An advisory committee, representative of major programs in the Bureau of Radiological Health, helped select the content for the revised edition, and a number of the Bureau's technical programs provided new data which are reflected in some of the charts and tables. Mr. John E. Munzer and Mr. Ralph E. Bunge of the training staff assumed major responsibility for work on the revision. The present text includes information unavailable ten years ago: a new chart of the nuclides, a universal decay table in place of individual isotope listings, microwave and laser glossaries, film-speed charts, depth-dose tables, and a "rules of thumb" section.

Although contributions from individuals and organizations are too numerous to list in detail, appreciation is expressed to all who made suggestions, provided material, and permitted the reprinting of data as acknowledged in the Handbook.

Mr. John C. Villforth, Director Bureau of Radiological Health	Mr. George R. Shultz, Director Training Institute

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SIGNS AND SYMBOLS

Mathematics

$+$	plus, addition, positive
$-$	minus, subtraction, negative
$\pm$	plus or minus, positive or negative
$\mp$	minus or plus, negative or positive
$\div$, $/$, $\_\_$	division
$\times$, $\cdot$, $()$	multiplication
$()$, $[]$	collection
$=$	equal to
$\neq$	not equal to
$\equiv$	identical to
$\cong$	equals approximately, congruent
$>$	greater than
$\ngtr$	not greater than
$\geq$, $\geqq$	greater than or equal to
$<$	less than
$\nless$	not less than
$\leq$, $\leqq$	less than or equal to
$::$	proportional to
$:$	ratio
$\sim$	similar to
$\propto$	varies as, proportional to
$\rightarrow$	approaches
∞	infinity
$\therefore$	therefore

$\sqrt{\ }$	square root
$\sqrt[n]{\ }$	nth root
a^n	nth power of a
a^{-n}	reciprocal of nth power of a, $= 1/a^n$
$\log$, $\log_{10}$	common logarithm
$\ln$, $\log_e$	natural logarithm
e, ϵ	base of natural logs, 2.71828183 . . .
π	pi, 3.14159265 . . .
$\angle$	angle
$\perp$	perpendicular to
$\parallel$	parallel to
n	any number
$\lvert n \rvert$	absolute value of n
$\bar{n}$	average value of n
n°	n degrees
n'	n minutes, n feet
n''	n seconds, n inches
$f(x)$	function of x
Δx	increment of x
dx	differential of x
Σ	summation of
$\sin$	sine
$\cos$	cosine
$\tan$	tangent

GREEK ALPHABET

Α	α	Alpha
Β	β	Beta
Γ	γ	Gamma
Δ	δ	Delta
Ε	ε	Epsilon
Ζ	ζ	Zeta
Η	η	Eta
Θ	θ	Theta
Ι	ι	Iota
Κ	κ	Kappa
Λ	λ	Lambda
Μ	μ	Mu
Ν	ν	Nu
Ξ	ξ	Xi
Ο	ο	Omicron
Π	π	Pi
Ρ	ρ	Rho
Σ	σ	Sigma
Τ	τ	Tau
Υ	υ	Upsilon
Φ	φ	Phi
Χ	χ	Chi
Ψ	ψ	Psi
Ω	ω	Omega

SIGNS AND SYMBOLS
ALPHABETICALLY BY NAME

about	ca
absolute	abs
absolute temperature (Kelvin)	K
absorption coefficient, energy, for air = $\tau + \kappa + \sigma_a$	μ_a
absorption coefficient, linear, effective or apparent	μ
absorption cross section in barns	σ_a
acceleration, linear	a
activation cross section in barns	σ_{ac}
activity, original	A_0
alkali	alk
alpha	α
alpha particle	α
alternating current	a.c.
ampere	A, amp.
angle between incident and scattered radiation	θ
angstrom	Å
anno (year)	a
aqua	aq.
aqueous	aq.
approximately	ca
area	A, σ
asymmetrical	asym.
atmosphere (atmospheric)	atm, atmos.
atomic mass number	A
atomic mass unit--^{12}C	u
atomic mass unit--^{16}O (old)	amu
atomic number	Z, at.no.
atomic weight	at.wt.
atto (prefix)	a
average	av, avg.
Avogadro constant	N_A
barn	b
barn (cross section)	σ
base of natural logarithm	e
barometer	bar.
beta	$\beta, \beta^-, {}^{0}_{-1}\beta$
beta particle	${}^{0}_{1}e, \beta, \beta^-, {}^{0}_{-1}\beta$
billion electron volt	BeV, GeV
biological decay constant	λ_b
biot	Bi
boiling point	b.p.
British thermal unit	Btu
buildup factor	b
calorie	cal
candela	cd
capacitance	C
Celsius	C
centi (prefix)	c
centigrade	C
centimeter	cm
centimeter-gram-second unit system	CGS
chemical	chem.
chemistry	chem.
circa	ca
circular	cir.
circular mill	c.m.
coefficient	coef.
cologarithm	colog
Compton absorption coefficient	σ_a
Compton collision coefficient	σ

Compton scatter coefficient	σ_s
concentrated	conc
concentration	C
concentration, air	X
cosine	cos
constant	const.
coulomb	C
count rate	R
counts per minute	cpm
cubic	cu.
cubic centimeter	cc, c.cm., cu.cm., cm^3
cubic foot	cu.ft.
cubic foot per minute	cfm
cubic inch	cu.in.
cubic meter	cu.m.,m^3
cubic millimeter	mm^3
cubic yard	cu.yd., yd^3
curie	Ci
curie (old)	c
cylinder	cyl.
day	d
decay constant	λ
deci (prefix)	d
decibel	dB
decontamination factor	DF
deka (prefix)	da
density, general	d
density, general or vapor	ρ
deuterium	D
deuteron	d
dielectric constant	ϵ
dilute	dil
disintegrations per minute	dpm
distribution factor	DF
dose	D
dose, absorbed	D
dose equivalent	DE
dyne	dyn
effective cross section in barns	σ_{eff}
electric charge	Q
electric field intensity	$\mathcal{E}$
electron	e,e^-,$_{-1}^{0}e$
electron capture	ϵ
electron volt	eV
energy	E,Q
exposure	X
Fahrenheit	F
farad	F
femto (prefix)	f
film density	D
finite increment	Δ
force	F
franklin	Fr
frequency	f
frequency (wave motion quantum theory)	ν
gamma	γ
gamma ray	γ
gastrointestinal	G.I.
gauss	G
giga (prefix)	G
gram	g
gram-molecule weight	mole
gravitational constant	G
half-life, biological	T_b
half-life, effective	T_{eff}
half-life, physical	$T_{\frac{1}{2}}$
half-value layer	HVL

hecto (prefix)	h
height	h
henry	H
hertz	Hz
hour	h
hundredweight	cwt
initial intensity	I_0
insoluble	insol.
intensity of radiation	I
joule	J
kayser	K
Kelvin	K
kilo (prefix)	k
kilogram	kg
kilovolt constant potential	kVcp
kilovolt peak	kVp
kilowatt	kW
kilowatt-hour	kWh
kinetic energy	K.E.
length	l
limit	lim
linear	lin
linear acceleration	a
linear distance	d,s
linear energy transfer	LET
liquid	liq
liter	l
logarithm	log
logarithm, common	$\log_{10}$
logarithm, natural (hyperbolic or Napierian logarithm)	ln,$\log_e$
logarithm to the base e	$\log_e$
logarithm to the base 10	$\log_{10}$
mass	m
mass of the hydrogen atom	m_H
mass of the neutron	m_n
mass of the proton	m_p
mass unit	mu
maximum	max
maxwell	Mx
maximum permissible concentration	MPC
maximum permissible dose	MPD
maximum permissible radionuclide body burden	q
mean free path	$\bar{l},\bar{\lambda}$
median lethal dose	LD_{50}
medium	med.
mega (prefix)	M
megaelectron volts	MeV
melting point	m.p.
meter	m
meter-kilograms-second-ampere system	MKSA
micro (prefix)	μ
microbar	μbar
microcurie	μCi
micromicro	p
micromicro (use p)	μμ
micromicron (use p)	μμ
micron (old)	μ
microseconds	μs
milli (prefix)	m
millibarns	mb
milligram	mg
milliliter	ml
millimeter	mm
millimicro	n
millimicron	mμ
minute	m,min
mole	mol
molecular weight	mol.wt.

molecule	mol.
momentum	p
nano (prefix)	n
negatron	e, e^-, $_{-1}^{0}e$
neutrino	ν
neutron	$_{0}^{1}n$, N
neutron number	N
newton	N
number	N, N_A, no.
number of radioactive atoms at zero time	N_0
number, original	N_0
numeric	N
observed standard deviation	S
oersted	Oe
ohm	Ω
original activity	A_0
ounce	oz
pair production coefficient	κ
pico (prefix)	p
pint	pt.
photoelectric coefficient	τ
photon energy	$h\nu$
Plank constant	h
poise	P
positron	e^+, $_{+1}^{0}e$, β^+, $_{+1}^{0}\beta$
potential	V
potential drop	V
potential energy	P.E.
pound	lb.
power factor	p.f.
precipitated	precip., pptd
pressure	p
Protective Action Guide	PAG
proton	p
quality factor	QF
quantity	Q
quantum	$h\nu$
radian, measure of angle; radioactivity	A
Radiation Protection Guide	RPG
Radioactivity Concentration Guide	RCG
radio frequency	rf
radius	r
radius, nuclear	R
range (radiation)	R
reaction energy in MeV	Q
relative biological effectiveness	RBE
resistance	R
resolving time	τ
rest mass of electron	m_e
revolutions per minute	rpm
roentgen	R
roentgen (old)	r
rutherford (obsolete)	Rd
scattering cross section in barns	σ_s
second	s
soluble	s, sol.
source to film distance	SFD
source to skin distance	SSD
square centimeter	cm^2
square meter	m^2
square millimeter	mm^2
standard temperature and pressure	s.t.p.
Stefan-Boltzman constant	k
temperature, absolute	T
temperature, general	t
tera (prefix)	T

tesla	T
theoretical standard deviation	σ
time	t
time increment	ϕ
total cross section in barns	σ_t
universal gas constant	R
velocity of light in vacuum	c
velocity, linear or particle	v
watt	W
wavelength	λ
weber	Wb
weight	wt.
work	W
work function	ϕ
year (anno, annum)	a,yr

Prefixes

deci	$(= 10^{-1})$	d	deka	$(= 10)$	da
centi	$(= 10^{-2})$	c	hecto	$(= 10^{2})$	h
milli	$(= 10^{-3})$	m	kilo	$(= 10^{3})$	k
micro	$(= 10^{-6})$	μ	mega	$(= 10^{6})$	M
nano	$(= 10^{-9})$	n	giga	$(= 10^{9})$	G
pico	$(= 10^{-12})$	p	tera	$(= 10^{12})$	T
femto	$(= 10^{-15})$	f			
atto	$(= 10^{-18})$	a			

SIGNS AND SYMBOLS
ALPHABETICALLY BY SYMBOL

a	acceleration, linear; anno (year); atto (prefix)
A	ampere; area; atomic mass number; radioactivity
Å	angstrom
abs	absolute
a.c.	alternating current
alk	alkali
amp.	ampere (use A)
amu	atomic mass unit--^{16}O (old) [use u)
A_o	activity, original
aq.	aqua; aqueous, water
asym.	asymmetrical
at.no.	atomic number
at.wt.	atomic weight
at, atmos	atmosphere (atmospheric)
av, avg.	average
b	barn; buildup factor
bar.	barometer
BeV	billion electron volt
Bi	biot
b.p.	boiling point
Btu	British thermal unit
c	velocity of light in vacuum; centi (prefix); curie (old) [use Ci)
C	capacitance; Celsius; centigrade; concentration; coulomb
ca	about; approximately; circa
cal	calorie
cc	cubic centimeter
cd	candela
cfm	cubic foot per minute
CGS	centimeter-gram-second system
chem.	chemical; chemistry
cir.	circular
c.m.	circular mill
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
coef.	coefficient
colog	cologarithm
conc	concentrated
const.	constant
cos	cosine
cpm	counts per minute
cu.	cubic
cu.cm.	cubic centimeter
cu.ft.	cubic foot
cu.in.	cubic inch
cu.m.	cubic meter
cu.yd.	cubic yard
cwt	hundredweight
cyl.	cylinder
d	day; deci (prefix); density, general; deuteron; distance, linear
D	density, film; deuterium; dose; absorbed dose
da	deka (prefix)
dB	decibel
DE	dose equivalent
DF	decontamination factor; distribution factor
dil	dilute
dpm	disintegration per minute
dyn	dyne
e	base of natural logarithm

E	energy
$\mathcal{E}$	electric field intensity
e, e^-	electron; negatron
$_{-1}^{0}e$	electron; beta particle;
e^+, $_{+1}^{0}e$	positron
f	femto (prefix); frequency
F	farad; fahrenheit; force
Fr	franklin
G	gravitational constant; gauss; giga (prefix)
GeV	giga electron volts
G.I.	gastrointestinal
h	Plank constant; hecto (prefix); height; hour
H	henry
$h\nu$	photon energy; quantum
HVL	half value layer
Hz	hertz
I	intensity of radiation
I_0	initial intensity
insol.	insoluble
J	joule
k	Stefan-Boltzman constant; kilo (prefix)
K	kayser; Kelvin; absolute temperature
K.E.	kinetic energy
kg	kilogram
kVp	kilovolt peak
kVcp	kilovolt constant potential
kW	kilowatt
kWh	kilowatt-hour
l	length; liter
$\bar{l}$	mean free path
lb.	pound
LD_{50}	median lethal dose
LET	linear energy transfer
lim	limit
lin	linear
liq	liquid
ln	natural logarithm
log	logarithm
$\log_e$	logarithm to the base e; natural, hyperbolic or Napierian logarithm
$\log_{10}$	common logarithm; logarithm to the base 10
m	mass; meter; milli (prefix); minute
m_e	rest mass of electron
m_H	mass of the hydrogen atom
m_n	mass of the neutron
m_p	mass of the proton
m^2	square meter
m^3	cubic meter
M	mega (prefix)
max	maximum
mb	millibarns
med.	medium
MeV	megaelectron volts
mg	milligram
min	minute
MKSA	meter-kilogram-second-ampere system
ml	milliliter
mm	millimeter
mm^2	square millimeter
mm^3	cubic millimeter
mol	mole; molecule
mol.wt.	molecular weight
mole	gram-molecule weight
m.p.	melting point
MPC	maximum permissible concentration
MPD	maximum permissible dose
mu	mass unit

Mx	maxwell
mμ	millimicron (use nano)
n	nano (prefix)
${}^{0}_{1}n$	neutron
N	neutron; neutron number; newton; number; numeric
N_A	Avogadro constant; number
no.	number
N_0	number of radioactive atoms at zero time; number, original
Oe	oersted
oz	ounce
p	momentum; pico (prefix); pressure
P	poise
PAG	Protective Action Guide
P.E.	potential energy
p.f.	power factor
precip., pptd	precipitated
pt.	point; pint
q	maximum permissible radionuclide body burden μCi
Q	electric charge; energy; quantity; reaction energy in MeV
QF	quality factor
r	radius; radial distance; roentgen (old)
R	range (radiation); rate, count; resistance; roentgen; universal gas constant; radius, nuclear
rad	radian, measure of angle
RBE	relative biological effectiveness
RCG	Radioactivity Concentration Guide
Rd	rutherford (obsolete)
rf	radio frequency
RPG	Radiation Protection Guide
rpm	revolutions per minute
s	distance, linear; second; soluble
S	observed standard deviation
SFD	source-to-film distance
sol.	soluble
SSD	source-to-skin distance
s.t.p.	standard temperature and pressure
t	temperature, general; time; ton
T	temperature, absolute; tera (prefix); tesla
T_b	half-life, biological
T_{eff}	half-life, effective
$T_{\frac{1}{2}}$	half-life, physical
u	atomic mass unit--${}^{12}C$
V	potential; potential drop; volt; volume
v	velocity, linear or particle
W	watt; work
Wb	weber
wt.	weight
x	absorber thickness
Z	atomic number
α	alpha; alpha particle
$\beta, \beta^-, {}^{0}_{-1}\beta$	beta; beta particle
$\beta^+, {}^{0}_{+1}\beta$	positron
γ	gamma; gamma ray
Δ	finite increment
ϵ	electron capture; dielectric constant
θ	angle between incident and scattered radiation
κ	pair production coefficient
λ	decay constant; wave length
$\bar{\lambda}$	mean free path

λ_b	biological decay constant
μ	absorption coefficient, effective or apparent, linear; micro; micron (prefix)
μ_a	$\tau + \kappa + \sigma_a$ = energy absorption coefficient for air
μbar	microbar
μCi	microcurie
μμ	micromicro; micromicron (use pico)
μs	microseconds
ν	frequency (wave motion quantum theory); neutrino
ρ	density, general or vapor
σ	area; barn (cross section) theoretical standard deviation; Compton collision coefficient
σ_a	absorption cross section in barns; Compton absorption coefficient
σ_{ac}	activation cross section in barns
σ_{eff}	effective cross section in barns
σ_s	Compton scatter coefficient; scattering cross section in barns
σ_t	total cross section in barns
τ	resolving time; photoelectric coefficient
ϕ	work function; time increment
Ω	ohm
χ	concentration, air

Prefixes

d	deci	(= 10^{-1})	da	deka	(= 10)
c	centi	(= 10^{-2})	h	hecto	(= 10^{2})
m	milli	(= 10^{-3})	k	kilo	(= 10^{3})
μ	micro	(= 10^{-6})	M	mega	(= 10^{6})
n	nano	(= 10^{-9})	G	giga	(= 10^{9})
p	pico	(= 10^{-12})	T	tera	(= 10^{12})
f	femto	(= 10^{-15})			
a	atto	(= 10^{-18})			

CONSTANTS

Quantity	Value (±)	MKSA	CGS
speed of light c =	2.997 925 3	10^{8} m s^{-1}	10^{10} cm s^{-1}
Boltzmann constant k =	1.380 54 18	10^{-23} J °K^{-1}	10^{-16} erg °K^{-1}
mass hydrogen atom m_H =	1.673 43 8	10^{-27} kg	10^{-24} g
proton mass m_p =	1.672 52 8	10^{-27} kg	10^{-24} g
	1.007 276 62 8	u	u
neutron m_n =	1.674 82 8	10^{-27} kg	10^{-24} g
	1.008 665 20 10	u	u
electron mass m_e =	9.109 1 4	10^{-31} kg	10^{-28} g
	5.485 97 3	10^{-4} u	10^{-4} u
m_p/m_e =	1.836 10 3	10^{3}	10^{3}
charge of positron e =	1.602 10 7	10^{-19} C	
e =	4.802 98 20		10^{-10} esu
e/c =	1.602 10 7		10^{-20} emu
charge to mass ratio e/m =	1.758 796 19	10^{11} C kg^{-1}	
e/m =	5.272 74 6		10^{17} esu g^{-1}
e/mc =	1.758 796 19		10^{7} emu g^{-1}
electron radius r_e =	2.817 77 11	10^{-15} m	10^{-13} cm
Thomson cross section $(8\pi/3)r_e^2$ =	6.651 6 5	10^{-29} m^{2}	10^{-25} cm^{2}
Zeeman splitting constant $e/4\pi mc$ =	4.668 58 4	10^{1} m^{-1} T^{-1}	
$e/4\pi mc^2$ =	4.668 58 4		10^{-5} cm^{-1} G^{-1}

CONSTANTS--Continued

Quantity	Value (±)	MKSA	CGS
Planck constant h =	6.625 6 5	10^{-34} J s	10^{-27} erg s
$h/2\pi = \hbar$ =	1.054 50 7	10^{-34} J s	10^{-27} erg s
h/e =	4.135 56 12	10^{-15} J s C^{-1}	
h/e =	1.397 47 4		10^{-17} erg s esu^{-1}
hc/e =	4.135 56 12		10^{-7} erg s emu^{-1}
h/k =	4.799 3 6	10^{-11} s °K	10^{-11} s °K
1st radiation constant $c_1 = 2\pi hc^2$ =	3.741 5 3	10^{-16} W m^2	10^{-5} erg $cm^2 s^{-1}$
2nd radiation constant $c_2 = hc/k$ =	1.438 79 19	10^{-2} m °K	cm °K
Wien's radiation law $\lambda_{max}T = c_2/4.965\ 114\ 23$ =	2.897 8 4	10^{-3} m °K	10^{-1} cm °K
Stefan-Boltzmann constant σ =	5.669 7 2 9	10^{-8} W m^{-2} °K^{-4}	10^{-5} erg $cm^{-2} s^{-1}$ °K^{-4}
fine structure constant α =	7.297 20 10	10^{-3}	10^{-3}
α^{-1} =	1.370 388 19	10^2	10^2
α^2 =	5.324 92 14	10^{-5}	10^{-5}
Bohr radius a_0 =	5.291 67 7	10^{-11} m	10^{-9} cm
Rydberg constant R_∞ =	1.097 373 1 3	$10^7 m^{-1}$	$10^5 cm^{-1}$
R_H =	1.096 775 8 3	$10^7 m^{-1}$	$10^5 cm^{-1}$
$R_\infty c$ =	3.289 842 4	$10^{15} s^{-1}$	$10^{15} s^{-1}$
$R_\infty hc$ =	2.179 72 17	10^{-18} J	10^{-11} erg

CONSTANTS--Continued

Quantity	Value (±)	MKSA	CGS
Bohr magneton μ_B =	9.273 2 6	10^{-24} J T^{-1}	10^{-21} erg G^{-1}
magnetic moment of electron μ_e =	9.284 0 6	10^{-24} J T^{-1}	10^{-21} erg G^{-1}
μ_e/μ_B =	1.001 159 615 15		
nuclear magneton μ_N =	5.050 5 4	10^{-27} J T^{-1}	10^{-24} erg G^{-1}
magnetic moment of proton μ_p =	1.410 49 13	10^{-26} J T^{-1}	10^{-23} erg G^{-1}
μ_p/μ_N =	2.792 76 7		
gyromagnetic ratio of proton γ_p =	2.675 19 2	10^{8} $s^{-1}T^{-1}$	10^{4} $s^{-1}G^{-1}$
Compton wave lengths: of electron $\lambda_{Ce} = h/m_e$ =	2.426 21 6	10^{-12} m	10^{-10} cm
$\lambda_C/2\pi$ =	3.861 44 9	10^{-13} m	10^{-11} cm
of proton $\lambda_{Cp} = h/m_pc$ =	1.321 40 4	10^{-15} m	10^{-13} cm
$\lambda_{Cp}/2\pi$ =	2.103 07 6	10^{-16} m	10^{-14} cm
of neutron $\lambda_{Cn} = h/m_nc$ =	1.319 58 4	10^{-15} m	10^{-13} cm
$\lambda_{Cn}/2\pi$ =	2.100 18	10^{-16} m	10^{-14} cm
Avogadro constant N_A =	6.022 52 28	10^{23} mol^{-1}	10^{23} mol^{-1}
molar volume of ideal gas at s.t.p. V_m =	2.241 36 30	10^{-2} $m^3 mol^{-1}$	10^{4} $cm^3 mol^{-1}$
molar gas constant R =	8.314 3 1 2	J mol^{-1} $^{\circ}K^{-1}$	10^{7} erg $mol^{-1\circ\circ}K^{-1}$
Faraday constant $F = N_Ae$ =	9.648 70 16	10^{4} C mol^{-1}	
$F = N_Ae$ =	2.892 61 5		10^{14} esu mol^{-1}
$F/c = N_Ae/c$ =	9.648 70 16		10^{3} emu mol^{-1}

CONSTANTS--Continued

Quantity	Value (±)	MKSA	CGS
curie Ci =	3.7×10^{10} dps		
base of natural logarithm e =	2.718 281 828 4		
gravitational acceleration g =	9.806 65	$m\ s^{-2}$	$10^{2}\ cm\ s^{-2}$
pi π =	3.141 592 653 59		
roentgen R =	$2.58 \times 10^{-4}\ C\ kg^{-1}$		
energy equivalent of electron mass mc^2 =		0.51 MeV	-
wave-length associated with 1 eV λ_0 =	1.239 81	10^{-6} m	10^{-4} cm
ratio of chemical to unified mass scales $r = M(O = 16)/M(^{12}C = 12)$ =	1.000 043 5		
$r = M(^{16}O = 16)/M(^{12}C = 12)$ =	1.000 317 92 2		
mass unit, unified mass scale $u = 1/N_A$ =	1.660 43	10^{-27} kg	10^{-24} g

CONVERSION FACTORS

AREA

Multiply # of ⟶ to obtain # of ⟵	by ⟶ by ⟵	to obtain # of Divide # of
barns	10^{-24}	cm^2
circular mils	7.854×10^{-7}	$in.^2$
cm^2	10^{24}	barns
cm^2	0.1550	$in.^2$
cm^2	1.076×10^{-3}	ft^2
cm^2	10^{-4}	m^2
ft^2	929.0	cm^2
ft^2	144	in^2
ft^2	9.290×10^{-2}	m^2
$in.^2$	6.452	cm^2
$in.^2$	6.944×10^{-3}	ft^2
$in.^2$	6.452×10^{-4}	m^2
m^2	1550	$in.^2$
m^2	10.76	ft^2
m^2	1.196	yd^2
m^2	3.861×10^{-7}	sq mi

DENSITY

cm^3	1.602×10^{-2}	ft^3/lb
ft^3/lb	62.43	cm^3/g
g/cm^3	62.43	lb/ft^3
lb/ft^3	1.602×10^{-2}	g/cm^3
$lb/in.^3$	27.68	g/cm^3
lb/gal	0.1198	g/cm^3

ELECTRICAL*

Multiply # of →	by →	to obtain # of
to obtain # of ←	by ←	Divide # of
amperes	1	coulombs
amperes	2.998×10^{9}	esu/sec
amperes	6.2418×10^{18}	electrons/sec
ampere-hours	3600.0	coulombs
ampere-hours	0.03731	faradays
coulombs	2.998×10^{9}	statcoulombs
coulombs	6.2418×10^{18}	electronic charges
coulombs	1.036×10^{-5}	faradays
faradays/sec	9.650×10^{4}	amperes
faradays	26.80	ampere-hours
faradays	9.650×10^{4}	coulombs
farads	10^{6}	microfarads
international amperes	0.999835	amperes (absolute)
international volts	1.00033	volts (absolute)
international ohms	1.000495	ohms (absolute)
international volt farady	9.654×10^{4}	joules
microfarads	10^{-6}	farads
microhms	10^{-12}	megohms
microhms	10^{-6}	ohms
watts	1	joules/sec

ENERGY

Btu	1.0548×10^{3}	joules (absolute)
Btu	0.25198	kg-cal
Btu	1.0548×10^{10}	ergs
Btu	2.930×10^{-4}	kW-hr
Btu	0.556	g-cal/g

---

* Units are absolute unless noted otherwise.

ENERGY--Continued

Multiply # of →	by →	to obtain # of
to obtain # of ←	by ←	Divide # of
eV	1.6021×10^{-12}	ergs
eV	1.6021×10^{-19}	joules (abs)
eV	10^{-3}	keV
ev	10^{-6}	MeV
ergs	10^{-7}	joules (abs)
ergs	6.2418×10^{5}	MeV
ergs	6.2418×10^{11}	eV
ergs	1.0	dyne-cm
ergs	9.480×10^{-11}	Btu
ergs	7.375×10^{-8}	ft-lb
ergs	2.390×10^{-8}	g-cal
ergs	1.020×10^{-3}	g-cm
gm-calories	3.968×10^{-3}	Btu
gm-calories	4.186×10^{7}	ergs
joules (abs)	10^{7}	ergs
joules (abs)	0.7376	ft-lb
joules (abs)	9.480×10^{-4}	Btu
g-cal/g	1.8	Btu/lb
kg-cal	3.968	Btu
kg-cal	3.087×10^{3}	ft-lb
ft-lb	1.356	joules (abs)
ft-lb	3.239×10^{-4}	kg-cal
kw-hr	2.247×10^{19}	MeV
kW-hr	3.60×10^{13}	ergs
MeV	1.6021×10^{-6}	ergs

Energy to mass conversions under miscellaneous

FISSION

Multiply # of ⟶ to obtain # of ⟵	by ⟶ by ⟵	to obtain # of Divide # of
Btu	1.28×10^{-8}	grams ^{235}U fissioned*
Btu	1.53×10^{-8}	grams ^{235}U destroyed*†
Btu	3.29×10^{13}	fissions
fission of 1 g ^{235}U	1	megawatt-days
fissions	8.9058×10^{-18}	kilowatt-hours
fissions*	3.204×10^{-4}	ergs
kilowatt-hours	2.7865×10^{17}	^{235}U fission neutrons*
kilowatts per kilogram ^{235}U	2.43×10^{10}	average thermal neutron flux in fuel*‡
megawatt-days per ton U	1.174×10^{-4}	% U atoms fissioned§
megawatts per ton U	$2.68\times10^{10}/E$≈	average thermal neutron flux in fuel*‡
neutrons per kilobarn	1×10^{21}	neutrons/cm^2
watts	3.121×10^{10}	fissions/sec

FLUID FLOW RATES

cm^3/min	2.19×10^{-3}	ft^3/min
cm^3/sec	8.64×10^{-2}	m^3/day
cm^3/sec	1.585×10^{-2}	gal/min
cm^3/sec	3.60	liters/hr
ft^3/min	4.72×10^{2}	cm^3/sec
ft^3/sec	4.488×10^{2}	gal/min
gal/min	2.228×10^{-3}	ft^3/sec
liters/hr	0.278	cm^3/sec
liters/min	15.851	gal/hr

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* At 200 MeV/fission.

† Thermal neutron spectrum ($\alpha = 0.193$).

‡ $\bar{\sigma}$ (fission = 500 barns).

§ At 200 MeV/fission, in ^{235}U-^{238}U mixture of low ^{235} content.

≈ E = enrichment in grams ^{235}U/gram total. No other fissionable isotope present.

Source: Nucleonics, Vol. 18, No. 11 (Nov. 1960), p. 209.

FLUID FLOW RATES--Continued

Multiply # of →	by →	to obtain # of
to obtain # of ←	by ←	Divide # of
liters/min	15.851	gal/hr
m^3/day	11.57	cm^3/sec
yd^3/min	0.450	ft^3/sec
yd^3/min	3.367	gal/sec
yd^3/min	12.74	liters/sec

LENGTH

angstroms (Å)	10^{-8}	cm
Å	10^{-10}	m
microns (μ)	10^{-3}	mm
μ	10^{-4}	cm
μ	10^{-6}	m
μ	3.937×10^{-5}	in.
mm	10^{-1}	cm
cm	0.3937	in.
cm	3.2808×10^{-2}	ft
cm	10^{-2}	m
m	39.370	in.
m	3.2808	ft
m	1.0936	yd
m	10^{-3}	km
m	6.2137×10^{-4}	miles
km	0.62137	miles
mils	10^{-3}	in.
mils	2.540×10^{-3}	cm
in.	10^3	mils
in.	2.5400	cm
ft	30.480	cm
rods	5.500	yd
miles	5280	ft
miles	1760	yd
miles	1.6094	km

MASS

Multiply # of →	by →	to obtain # of
to obtain # of ←	by ←	Divide # of
mg	10^{-3}	g
mg	3.527×10^{-5}	oz avdp
mg	1.543×10^{-2}	grains
g	3.527×10^{-2}	oz avdp
g	10^{-3}	kg
g	980.7	dynes
g	2.205×10^{-3}	lb
kg	2.205	lb
kg	0.0685	slugs
kg	9.807×10^{5}	dynes
lb	4.448×10^{5}	dynes
lb	453.592	g
lb	0.4536	kg
lb	16	oz avdp
lb	0.0311	slugs
dynes	1.020×10^{-3}	g
dynes	2.248×10^{-6}	lb
u (unified-- ^{12}C scale)	1.66043×10^{-27}	kg
amu (physical-- ^{16}O scale)	1.65980×10^{-27}	kg
oz	28.35	g
oz	6.25×10^{-2}	lb

Mass to energy conversions under miscellaneous.

MISCELLANEOUS

temperature $^{\circ}C = (^{\circ}F-32)/1.8 = (^{\circ}F-32)\ 5/9$

$^{\circ}F = 1.8^{\circ}C + 32 = (9/5)\ ^{\circ}C + 32$

$^{\circ}K = {}^{\circ}C + 273.16$

wavelength to energy conversion

$keV = 12.40/\text{Å}$

$eV = 1.240\times10^{-6}/m$

MISCELLANEOUS--Continued

Multiply # of →	by →	to obtain # of
to obtain # of ←	by ←	Divide # of
radians	57.296	degrees
eV	1.78258×10^{-33}	grams
eV	1.07356×10^{-9}	u
erg	1.11265×10^{-21}	grams
proton masses	938.256	MeV
neutron masses	939.550	MeV
electron masses	511.006	keV
u (amu on ^{12}C scale)	931.478	MeV

POWER

Multiply # of →	by →	to obtain # of
Btu/hr	0.2162	ft-lb/sec
Btu/hr	0.0700	gm-cal/sec
Btu/hr	3.929×10^{-4}	horsepower
Btu/hr	0.2930	watts
Btu/min	12.97	ft-lb/sec
Btu/min	0.02357	horsepower
Btu/min	0.01758	kilowatts
Btu/min	17.58	watts
horsepower	42.42	Btu/min
horsepower	33,000	ft-lb/min
horsepower	550	ft-lb/sec
horsepower	10.69	kg-cal/min
horsepower	0.7457	kilowatts
horsepower	4.655×10^{15}	MeV/sec
kg-cal/min	9.356×10^{-2}	horsepower
kilowatts	14.33	kg-cal/min
kilowatts	1.341	horsepower
kilowatts	6.243×10^{15}	MeV/sec
watts	10^{7}	ergs/sec
watts	0.7376	ft-lb/sec
watts	3.414	Btu/hr

POWER--Continued

Multiply # of ⟶	by ⟶	to obtain # of
to obtain # of ⟵	by ⟵	Divide # of
watts	0.05690	Btu/min
watts	0.01433	kg-cal/min
ergs/sec	5.688×10^{-9}	Btu/min
ergs/sec	4.425×10^{-6}	ft-lb/min
ergs/sec	1.433×10^{-9}	kg-cal/min

PRESSURE

atm	14.696	lb/in.^{2}
atm	760	mm Hg (0° C)
atm	76.0	cm Hg (0° C)
atm	1.0133	bars
atm	1.0332×10^{3}	g/cm^2
atm	29.921	in. Hg (0° C)
cm Hg	0.1934	lb/in.^{2}
cm Hg	1.316×10^{-2}	atm
cm Hg	0.4465	ft of H_2O
in. Hg	0.4912	lb/in.^{2}
g/cm^2	1.4223×10^{-2}	lb/in.^{2}
bars	10^{6}	dynes/cm^2
bars	14.504	lb/in.^{2}
dynes/cm^2	1.4504×10^{-5}	lb/in.^{2}
dynes/cm^2	1.0197×10^{-3}	g/cm^2
lb/in.^{2}	27.673	in. of H_2O (4° C)
lb/in.^{2}	2.3066	ft of H_2O (4° C)
lb/in.^{2}	6.805×10^{-2}	atm
lb/in.^{2}	2.036	in. Hg (0° C)
lb/in.^{2}	5.1715	cm Hg
lb/in.^{2}	51.715	mm Hg
ft of H_2O	2.230	cm Hg

RADIOLOGICAL UNITS

Multiply # of ⟶ to obtain # of ⟵	by ⟶ by ⟵	to obtain # of Divide # of
curies	3.700×10^{10}	dis/sec
curies	2.220×10^{12}	dis/min
curies	10^{3}	millicuries
curies	10^{6}	microcuries
curies	10^{12}	picocuries
curies	10^{-3}	kilocuries
dis/min	4.505×10^{-10}	millicuries
dis/min	4.505×10^{-7}	microcuries
dis/sec	2.703×10^{-8}	millicuries
dis/sec	2.703×10^{-5}	microcuries
kilocuries	10^{3}	curies
microcuries	3.700×10^{4}	dis/sec
microcuries	2.220×10^{6}	dis/min
millicuries	3.700×10^{7}	dis/sec
millicuries	2.220×10^{9}	dis/min
R	2.58×10^{-4}	C/kg of air
R	1	esu/cm^3 of air (s.t.p.)
R	2.082×10^{9}	ion prs/cm^3 of air (s.t.p.)
R	1.610×10^{12}	ion prs/g of air
R (33.7 eV/ion pr.)	7.02×10^{4} 7.02×10^{4}	MeV/cm^3 of air (s.t.p.)
R (33.7 eV/ion pr.)	5.43×10^{7}	MeV/g of air
R (33.7 eV/ion pr.)	86.9	ergs/g of air
R (33.7 eV/ion pr.)	2.08×10^{-6}	g-cal/g of air
R (33.7 eV/ion pr.)	≈98	ergs/g of soft tissue
rads	0.01	J/kg
rads	100	ergs/g
rads	8.071×10^{4}	MeV/cm^3 of air (s.t.p.)
rads	6.242×10^{7}	MeV/g
rads	10^{-5}	watt-sec/g

RADIOLOGICAL UNITS--Continued

Multiply # of ⟶	by ⟶	to obtain # of
to obtain # of ⟵	by ⟵	Divide # of
rads (33.7 ev/ion pr.)	2.39×10^{9}	ion prs/cm^3 of air (s.t.p.)
μCi/cm^3 (μCi/ml)	2.22×10^{12}	dpm/m^3
μCi/cm^3	2.22×10^{9}	dpm/liter
dpm/m^3	0.4505	pCi/m^3

TIME

days	86,400	sec
days	1440	min
years (365 days)	3.1536×10^{7}	sec
years	5.256×10^{5}	min
years	8.760×10^{3}	hr
work weeks	1.44×10^{5}	sec
work weeks	40	hr
work months	4.2	work weeks
work months	168	hr

VELOCITY

cm/sec	0.6000	m/min
cm/sec	0.0360	km/hr
cm/sec	0.032808	ft/sec
cm/sec	1.9685	ft/min
cm/sec	3.728×10^{-4}	mi/min
cm/sec	0.02237	mph
m/min	1.667	cm/sec
m/min	5.468×10^{-2}	ft/sec
m/min	3.728×10^{-2}	mph
ft/sec	18.29	m/min
ft/sec	0.6818	mph
ft/min	0.5080	cm/sec
ft/min	1.667×10^{-2}	ft/sec
ft/min	1.136×10^{-2}	mph
mph	44.70	cm/sec

VELOCITY--Continued

Multiply # of ⟶ to obtain # of ⟵	by ⟶ by ⟵	to obtain # of Divide # of
mph	88	ft/min
mph	1.467	ft/sec
mph	26.82	m/min

VOLUME

cm^3 (cc)	0.99997	ml
cm^3	6.1023×10^{-2}	$in.^3$
cm^3	10^{-6}	m^3
cm^3	9.9997×10^{-4}	liters
cm^3	3.5314×10^{-5}	ft^3
m^3	35.314	ft^3
m^3	2.642×10^{2}	gal
m^3	9.9997×10^{2}	liters
$in.^3$	16.387	cm^3
$in.^3$	5.787×10^{-4}	ft^3
$in.^3$	1.639×10^{-2}	liters
$in.^3$	4.329×10^{-3}	gal
ft^3	2.832×10^{-2}	m^3
ft^3	7.481	gal
ft^3	28.32	liters
ft^3	1728	$in.^3$
gal (U.S.)	231.0	$in.^3$
gal	0.13368	ft^3
liters	33.8147	fluid oz
liters	1.05671	quarts
liters	0.26418	gal
gm moles (gas)	22.4	liters (s.t.p.)

C. WAVE AND QUANTUM RELATIONS

Unless otherwise noted, symbols and dimensions in this section are used consistently as follows:

v = velocity of wave or particle (cm/sec)
h = Planck constant (6.6×10^{-27} erg sec)
ν = frequency of wave or quanta (hertz)
λ = wavelength (cm)
λ_o = wavelength of incident radiation (angstroms)
λ_θ = wavelength of scattered radiation at angle θ (angstroms)
E = energy (ergs)
θ = angle between incident and scattered radiation
c = velocity of light (3×10^{10} cm/sec)
m = mass of particle (gm)
ϕ = work function (ergs)

(1) Wave Equation

Wave velocity (v or c) = $\lambda\nu$

(2) Associated Wavelength of a Particle

$$\text{Wavelength} = \lambda = \frac{h}{mv}$$

(3) Photoelectric Equation

$$E = \phi + \tfrac{1}{2}mv^2$$

(4) Photon Energy

$$E = h\nu$$

$$E = \frac{hc}{\lambda}$$

$$\text{Energy in electron volts} = \frac{1.242 \times 10^4}{\text{Wavelength in angstroms}}$$

(5) Mass-Energy Relation

$$E = mc^2$$

(6) Momentum of Photon

$$mv = \frac{h}{\lambda}$$

(7) Compton Scattering of Gamma and X Rays

$$\lambda_\theta = \lambda_o + 0.0242\,(1 - \cos\theta)$$

D. ELECTROSTATICS

The following units apply in this section:

F = force (dynes)
Q = electrostatic charge (statcoulombs)

s = distance (cm)

V = potential (statvolts)

C = capacitance (statfarads)

W = work (ergs)

ϵ = dielectric constant

(1) Force Between Two Charges, a and b (Coulomb's Law)

$$F = \frac{Q_a Q_b}{\epsilon s^2}$$

(2) Work

$$W = Q\,V$$

(3) Capacitance

$$C = Q/V$$

(4) Potential

$$V = Q/s$$

E. RADIOACTIVE DECAY

The following symbols will be used in this section:

N_0 = number of nuclei at some original time

N = number of nuclei remaining after a time interval, t

I_0 = intensity of radiation at some original time

I = intensity of radiation after a time interval, t

A_0 = activity of sample at some original time

A = activity remaining after a time interval, t

λ = decay constant for the particular radioactive element

e = base of natural logarithms; 2.718 . . .

t = elapsed time

$T_{\frac{1}{2}}$ = half-life of a particular radioactive element

n = $t/T_{\frac{1}{2}}$ = number of half-lives

(1) $N = N_0 e^{-\lambda t}$ or $N = N_0 e^{-0.693t/T_{\frac{1}{2}}}$

(2) $A = A_0 e^{-\lambda t}$ or $A = A_0 e^{-0.693t/T_{\frac{1}{2}}}$

(3) $I = I_0 e^{-\lambda t}$ or $I = I_0 e^{-0.693t/T_{\frac{1}{2}}}$

(4) $N = N_0 e^{-n}$ or $N/N_0 = 1/2^n$

Decay Constant

(5) $\lambda = 0.693/T_{\frac{1}{2}}$

Fission Product Decay*

(6) $I_1 t_1^{-1.2} = I_2 t_2^{-1.2}$

where I_1 = radiation intensity at time t_1 (>4h) after fission

I_2 = radiation intensity at time t_2 (<200 days) after fission

F. SPECIFIC ACTIVITY (Isotopic)

Specific Activity

$\lambda N = 0.693 N / T_{\frac{1}{2}}$ = dis/sec/gm

where $T_{\frac{1}{2}}$ = half-life (seconds)

N = number of atoms per gram

Specific Activity

$\lambda N / (3.7 \times 10^{10}) = \dfrac{N \times 1.873 \times 10^{-11}}{T_{\frac{1}{2}}}$ = curies/gm

G. RADIATION ABSORPTION

(1) Alpha Particle Range

$R_\alpha = 0.56E$ ($E<4$ MeV)

$R_\alpha = 1.24E - 2.62$ ($4<E<8$ MeV)

where R_α = range in cm of air at 1 atm and 15°C

E = energy, MeV

(2) Beta Particle Range

For $0.01 \leq E \leq 2.5$ MeV

$R = 412\, E^{1.265 - 0.0954 \ln E}$

$\ln E = 6.63 - 3.2376\, [10.2146 - \ln R]^{\frac{1}{2}}$

where R = range in mg/cm^2

E = max. energy, MeV

For $E \geq 2.5$ MeV

$R = 530\, E - 106$

where R, E same as above

Sargent's rule ($E > 0.8$ MeV)

$R = 0.526\, E - 0.094$

where R = range, gm/cm^2

E = max. energy, MeV

Feather's rule ($E > 0.6$ MeV)

$R = 0.542\, E - 0.133$

where R, E same as for Sargeant's rule

(3) Gamma Ray Absorption

The following symbols will be used in this section:

I_0 = original radiation exposure rate

I = attenuated radiation exposure rate

μ = linear absorption coefficient (cm^{-1}) $= \dfrac{0.693}{x_{\frac{1}{2}}}$

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*See "The Effects of Nuclear Weapons," 1962, §9.170-9.177

μ/ρ = mass absorption coefficient (cm^2/gm)

ρ = absorber density (gm/cm^3)

x = absorber thickness (cm)

$x_{\frac{1}{2}}$ = half-value layer of absorber (cm)

e = base of natural logarithms (2.718 . . .)

b = "buildup" factor

For monoenergetic or monochromatic narrow-beam radiation:

$I = I_0 e^{-\mu x}$ or $I = I_0 e^{-(\mu/\rho)(\rho)(x)}$

For monoenergetic or monochromatic wide-beam radiation:

$I = bI_0 e^{-\mu x}$

(4) Neutron Absorption (for a collimated beam of monoenergetic neutrons)

$I = I_0 e^{-\sigma N x}$

where I_0 = initial neutron intensities

I = final neutron intensities

N = number of atoms per cc in the absorber

σ = cross section (square centimeters)

x = thickness of absorber (cm)

e = base of the natural logarithm (2.718 . . .)

Since this equation is only an approximation of neutron attenuation, average neutron energies can be used for determining the value of σ. The equation is not accurate enough to justify the use of neutron buildup factors.

(5) Approximate Range - Energy Relation for Protons*

$R = (E/9.3)^{1.8}$

where E = energy in MeV (few MeV to 200 MeV)

R = range in meters in air

H. BETA PARTICLE COUNTING

(1) Self-Absorption

$$\frac{R_0}{R} = \frac{1}{mx}(1 - e^{-mx})$$

where R_0 = measured counting rate

R = true counting rate

x = sample thickness (mg/cm^2)

m = absorption coefficient (cm^2/mg) [See NBS Handbook No. 51, p. 26]

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*Segre, Emilio, "Experimental Nuclear Physics," Vol. 1, New York: John Wiley & Sons, Inc., 1953.

(2) Resolving Time Determination

$$\tau = \frac{R_1 + R_2 - R_{12}}{2\,(R_1\ R_2)}$$

where τ = resolving time, seconds

R_1 = counting rate, source 1 (c/s)

R_2 = counting rate, source 2 (c/s)

R_{12} = counting rate, combined sources 1 and 2 (c/s)

(3) Resolving Time Correction

$$R = \frac{R_0}{1 - R_0 \tau}$$

where R = true counting rate (c/s)

R_0 = observed counting rate (c/s)

τ = resolving time, seconds

I. STATISTICS OF COUNTING*

n = number of counts, one observation

t = counting time, one observation

$\bar{n}$ = mean number of counts, series of observations

$\bar{t}$ = mean counting time, series of observations

m = number of observations

σ = theoretical standard deviation

S_t = observed standard deviation of the time required to record a preset number of counts

S_n = observed mean standard deviation of the number of counts recorded in a preset time

r = average number of counts per unit time

(1) Theoretical Standard Deviation

(a) $\sigma_n = \sqrt{rt} \cong \sqrt{n}$ for single observation

(b) $\sigma_{\bar{n}} = \sqrt{rt/m} \cong \sqrt{\bar{n}/m}$ for average number of counts/interval

(2) Observed (Experimental) Standard Deviation

(a) Series of observations, preset time

$$S_n = \left[\sum_{i=1}^{m} (n_i - \bar{n})^2/(m - 1)\right]^{\frac{1}{2}}$$

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* Bleuler, Ernst, and Goldsmith, George J., "Experimental Nucleonics," New York: Holt, Rinehart & Winston, Inc., 1952.

(b) Series of observations, preset count

$$S_t = \left[\sum_{i=1}^{n}(t_i - \bar{t})^2/(m-1)\right]^{\frac{1}{2}}$$

$$S_n = (n/\bar{t})S_t$$

(c) Reliability factor

$$R.F. = S_n/\sigma_{\bar{n}}$$

J. CALIBRATION PROCEDURES

Gamma Emitter Dose in Air

(1) Exposure Rate (from a point source)

$I_\gamma = 0.156\ n\ E\ (10^5\ \mu_a)$ (Equation assumes that one ion pair in air causes an average energy expenditure of 32.7 electron volts.)

where I_γ = mR/hr at 1 meter per mCi

n = gamma quanta per disintegration

E = energy of gamma quanta in MeV

μ_a = energy absorption coefficient for gamma in air (S.T.P.) in cm^{-1}

(2) Exposure Rate (from point source of radium, 0.5 mm Pt cover)

$mR/hr = \frac{mg\ of\ Ra}{yd^2}$ where yd = distance to source (yd)

$mR/hr = \frac{8400\ mg\ of\ Ra}{cm^2}$ cm = distance (cm)

(3) Exposure Rate, Approximate (from any gamma point source)

R/hr at 1 foot $\cong$ 6 C E n where C = number of curies

mR/hr/mCi at 1 meter $\cong$ 0.5 nE E = gamma ray energy (MeV)

n = gamma quanta/dis

(4) Exposure Rate (from any gamma point source)

$mR/hr = nI_\gamma/s^2$ where n = number of millicuries

I_γ = mR/hr at 1 meter per mCi

s = distance (meters)

(5) Exposure Rate (from a linear gamma emitter source)

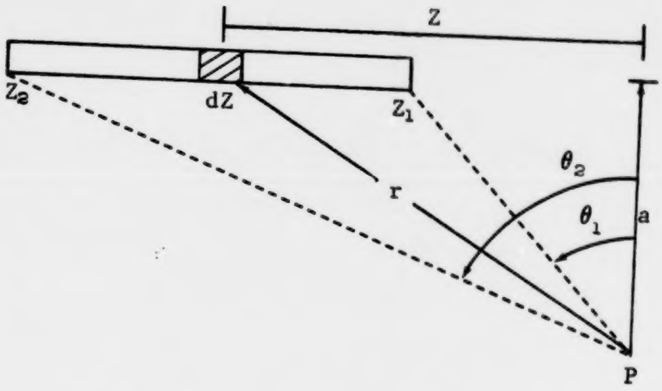
The following terminology will be used:

S = source activity in photons per second per unit length

ϕ = flux at point of interest in photons per square centimeter per second

r = distance from source to point of interest, P

θ = angle in degrees



$$\phi = \int_{Z_1}^{Z_2} \frac{S(dZ)}{4\pi r^2}$$

$$\phi = \frac{S}{4\pi a}(\theta_2 - \theta_1)$$

K. INTERNAL RADIATION DOSAGE

(1) Biological Half-Life

$$T_b = \frac{0.693}{\lambda_b}$$

where λ_b = biological decay constant

T_b = biological half-life

(2) Effective Half-Life

$$T_{eff} = \frac{(T_{\frac{1}{2}})(T_b)}{T_{\frac{1}{2}} + T_b}$$

where T_{eff} = effective half-life

$T_{\frac{1}{2}}$ = radioactive (physical) half-life

T_b = biological half-life

(3) Beta Emitter Dose

$$D = 73.8\ E\ T_{eff} C\ (1 - e^{-\lambda_{eff}\ t})$$

where D = dose (rads)

E = average energy of beta particle (MeV)

T_{eff} = effective half-life

C = µCi/gm of radionuclide in tissue

λ_{eff} = effective decay constant (day^{-1})

t = time (day)

L. DECONTAMINATION FACTOR

$$\text{D.F.} = \frac{\text{Initial Activity}}{\text{Final Activity}}$$

M. ISOTOPIC DILUTION

(1) Single Addition Method

$$w = w'\left(\frac{SpA'}{SpA} - 1\right)$$

where w = total weight of diluent material (weight of stable material)

w' = total weight of labeled material (weight of radioactive material)

SpA' = specific activity of labeled material

SpA = specific activity of mixture

(2) Double Dilution

$$\text{(a)}\quad S = \frac{S_1^1\ S_2\ (G_1 - G_2)}{S_2\ G_2 - S_1\ G_1}$$

$$\text{(b)}\quad Z = \frac{S_1\ G_2 - S_1\ G_1}{S_1 - S_2}$$

where S_0 = initial specific activity

S_1 = specific activity of first dilution

S_2 = specific activity of second dilution

G_1 = weight of carrier added for first dilution

G_2 = weight of carrier added for second dilution

Z = weight of original radioactive material

N. NEUTRON ACTIVATION METHODS

Thin Target*

$$A\phi = k\sigma_{ac}\,f\ n\ (1 - e^{-\lambda t})\ e^{-\lambda\phi}$$

where A_ϕ = measured activity in net counts per second at time ϕ

ϕ = time increment between end of irradiation and the time at which the target is counted

k = efficiency of the counter for measuring the induced radioactivity

σ_{ac} = activation across section for neutron capture by the target material, square centimeters per atom per neutron

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*A thin target is one which will not reduce the neutron flux by more than the error permitted for the experiment.

f = flux of neutrons, neutrons per square centimeter per second

n = total number of target nuclei

λ = disintegration constant of radioactive material

t = time duration of exposure to neutron flux

e = base of natural logarithm (2.718 . . .)

O. GEOMETRY OF A COUNTER

Point Source

$G = 0.5\ (1 - \cos \alpha) = \sin^2 \frac{1}{2}\alpha$

where α = arc tan $\frac{r}{d}$

r = radius of counter window or phosphor

d = distance between counter and source

G = geometry factor

SQUARES AND SQUARE ROOTS

N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$
1.00	1.0000	1.00000	3.16228	**1.60**	2.5600	1.26491	4.00000	**2.20**	4.8400	1.48324	4.69042
1.01	1.0201	1.00499	3.17805	1.61	2.5921	1.26886	4.01248	2.21	4.8841	1.48661	4.70106
1.02	1.0404	1.00995	3.19374	1.62	2.6244	1.27279	4.02492	2.22	4.9284	1.48997	4.71169
1.03	1.0609	1.01489	3.20936	1.63	2.6569	1.27671	4.03733	2.23	4.9729	1.49332	4.72229
1.04	1.0816	1.01980	3.22490	1.64	2.6896	1.28062	4.04969	2.24	5.0176	1.49666	4.73286
1.05	1.1025	1.02470	3.24037	**1.65**	2.7225	1.28452	4.06202	**2.25**	5.0625	1.50000	4.74342
1.06	1.1236	1.02956	3.25576	1.66	2.7556	1.28841	4.07431	2.26	5.1076	1.50333	4.75395
1.07	1.1449	1.03441	3.27109	1.67	2.7889	1.29228	4.08656	2.27	5.1529	1.50665	4.76445
1.08	1.1664	1.03923	3.28634	1.68	2.8224	1.29615	4.09878	2.28	5.1984	1.50997	4.77493
1.09	1.1881	1.04403	3.30151	1.69	2.8561	1.30000	4.11096	2.29	5.2441	1.51327	4.78539
1.10	1.2100	1.04881	3.31662	**1.70**	2.8900	1.30384	4.12311	**2.30**	5.2900	1.51658	4.79583
1.11	1.2321	1.05357	3.33167	1.71	2.9241	1.30767	4.13521	2.31	5.3361	1.51987	4.80625
1.12	1.2544	1.05830	3.34664	1.72	2.9584	1.31149	4.14729	2.32	5.3824	1.52315	4.81664
1.13	1.2769	1.06301	3.36155	1.73	2.9929	1.31529	4.15933	2.33	5.4289	1.52643	4.82701
1.14	1.2996	1.06771	3.37639	1.74	3.0276	1.31909	4.17133	2.34	5.4756	1.52971	4.83735
1.15	1.3225	1.07238	3.39116	**1.75**	3.0625	1.32288	4.18330	**2.35**	5.5225	1.53297	4.84768
1.16	1.3456	1.07703	3.40588	1.76	3.0976	1.32665	4.19524	2.36	5.5696	1.53623	4.85798
1.17	1.3689	1.08167	3.42053	1.77	3.1329	1.33041	4.20714	2.37	5.6169	1.53948	4.86826
1.18	1.3924	1.08628	3.43511	1.78	3.1684	1.33417	4.21900	2.38	5.6644	1.54272	4.87852
1.19	1.4161	1.09087	3.44964	1.79	3.2041	1.33791	4.23084	2.39	5.7121	1.54596	4.88876
1.20	1.4400	1.09545	3.46410	**1.80**	3.2400	1.34164	4.24264	**2.40**	5.7600	1.54919	4.89898
1.21	1.4641	1.10000	3.47851	1.81	3.2761	1.34536	4.25441	2.41	5.8081	1.55242	4.90918
1.22	1.4884	1.10454	3.49285	1.82	3.3124	1.34907	4.26615	2.42	5.8564	1.55563	4.91935
1.23	1.5129	1.10905	3.50714	1.83	3.3489	1.35277	4.27785	2.43	5.9049	1.55885	4.92950
1.24	1.5376	1.11355	3.52136	1.84	3.3856	1.35647	4.28952	2.44	5.9536	1.56205	4.93964
1.25	1.5625	1.11803	3.53553	**1.85**	3.4225	1.36015	4.30116	**2.45**	6.0025	1.56525	4.94975
1.26	1.5876	1.12250	3.54965	1.86	3.4596	1.36382	4.31277	2.46	6.0516	1.56844	4.95984
1.27	1.6129	1.12694	3.56371	1.87	3.4969	1.36748	4.32435	2.47	6.1009	1.57162	4.96991
1.28	1.6384	1.13137	3.57771	1.88	3.5344	1.37113	4.33590	2.48	6.1504	1.57480	4.97996
1.29	1.6641	1.13578	3.59166	1.89	3.5721	1.37477	4.34741	2.49	6.2001	1.57797	4.98999
1.30	1.6900	1.14018	3.60555	**1.90**	3.6100	1.37840	4.35890	**2.50**	6.2500	1.58114	5.00000
1.31	1.7161	1.14455	3.61939	1.91	3.6481	1.38203	4.37035	2.51	6.3001	1.58430	5.00999
1.32	1.7424	1.14891	3.63318	1.92	3.6864	1.38564	4.38178	2.52	6.3504	1.58745	5.01996
1.33	1.7689	1.15326	3.64692	1.93	3.7249	1.38924	4.39318	2.53	6.4009	1.59060	5.02991
1.34	1.7956	1.15758	3.66060	1.94	3.7636	1.39284	4.40454	2.54	6.4516	1.59374	5.03984
1.35	1.8225	1.16190	3.67423	**1.95**	3.8025	1.39642	4.41588	**2.55**	6.5025	1.59687	5.04975
1.36	1.8496	1.16619	3.68782	1.96	3.8416	1.40000	4.42719	2.56	6.5536	1.60000	5.05964
1.37	1.8769	1.17047	3.70135	1.97	3.8809	1.40357	4.43847	2.57	6.6049	1.60312	5.06952
1.38	1.9044	1.17473	3.71484	1.98	3.9204	1.40712	4.44972	2.58	6.6564	1.60624	5.07937
1.39	1.9321	1.17898	3.72827	1.99	3.9601	1.41067	4.46094	2.59	6.7081	1.60935	5.08920
1.40	1.9600	1.18322	3.74166	**2.00**	4.0000	1.41421	4.47214	**2.60**	6.7600	1.61245	5.09902
1.41	1.9881	1.18743	3.75500	2.01	4.0401	1.41774	4.48330	2.61	6.8121	1.61555	5.10882
1.42	2.0164	1.19164	3.76829	2.02	4.0804	1.42127	4.49444	2.62	6.8644	1.61864	5.11859
1.43	2.0449	1.19583	3.78153	2.03	4.1209	1.42478	4.50555	2.63	6.9169	1.62173	5.12835
1.44	2.0736	1.20000	3.79473	2.04	4.1616	1.42829	4.51664	2.64	6.9696	1.62481	5.13809
1.45	2.1025	1.20416	3.80789	**2.05**	4.2025	1.43178	4.52769	**2.65**	7.0225	1.62788	5.14782
1.46	2.1316	1.20830	3.82099	2.06	4.2436	1.43527	4.53872	2.66	7.0756	1.63095	5.15752
1.47	2.1609	1.21244	3.83406	2.07	4.2849	1.43875	4.54973	2.67	7.1289	1.63401	5.16720
1.48	2.1904	1.21655	3.84708	2.08	4.3264	1.44222	4.56070	2.68	7.1824	1.63707	5.17687
1.49	2.2201	1.22066	3.86005	2.09	4.3681	1.44568	4.57165	2.69	7.2361	1.64012	5.18652
1.50	2.2500	1.22474	3.87298	**2.10**	4.4100	1.44914	4.58258	**2.70**	7.2900	1.64317	5.19615
1.51	2.2801	1.22882	3.88587	2.11	4.4521	1.45258	4.59347	2.71	7.3441	1.64621	5.20577
1.52	2.3104	1.23288	3.89872	2.12	4.4944	1.45602	4.60435	2.72	7.3984	1.64924	5.21536
1.53	2.3409	1.23693	3.91152	2.13	4.5369	1.45945	4.61519	2.73	7.4529	1.65227	5.22494
1.54	2.3716	1.24097	3.92428	2.14	4.5796	1.46287	4.62601	2.74	7.5076	1.65529	5.23450
1.55	2.4025	1.24499	3.93700	**2.15**	4.6225	1.46629	4.63681	**2.75**	7.5625	1.65831	5.24404
1.56	2.4336	1.24900	3.94968	2.16	4.6656	1.46969	4.64758	2.76	7.6176	1.66132	5.25357
1.57	2.4649	1.25300	3.96232	2.17	4.7089	1.47309	4.65833	2.77	7.6729	1.66433	5.26308
1.58	2.4964	1.25698	3.97492	2.18	4.7524	1.47648	4.66905	2.78	7.7284	1.66733	5.27257
1.59	2.5281	1.26095	3.98748	2.19	4.7961	1.47986	4.67974	2.79	7.7841	1.67033	5.28205
1.60	2.5600	1.26491	4.00000	**2.20**	4.8400	1.48324	4.69042	**2.80**	7.8400	1.67332	5.29150

SQUARES AND SQUARE ROOTS

N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$
2.80	7.8400	1.67332	5.29150	**3.40**	11.5600	1.84391	5.83095	**4.00**	16.0000	2.00000	6.32456
2.81	7.8961	1.67631	5.30094	3.41	11.6281	1.84662	5.83952	4.01	16.0801	2.00250	6.33246
2.82	7.9524	1.67929	5.31037	3.42	11.6964	1.84932	5.84808	4.02	16.1604	2.00499	6.34035
2.83	8.0089	1.68226	5.31977	3.43	11.7649	1.85203	5.85662	4.03	16.2409	2.00749	6.34823
2.84	8.0656	1.68523	5.32917	3.44	11.8336	1.85472	5.86515	4.04	16.3216	2.00998	6.35610
2.85	8.1225	1.68819	5.33854	**3.45**	11.9025	1.85742	5.87367	**4.05**	16.4025	2.01246	6.36396
2.86	8.1796	1.69115	5.34790	3.46	11.9716	1.86011	5.88218	4.06	16.4836	2.01494	6.37181
2.87	8.2369	1.69411	5.35724	3.47	12.0409	1.86279	5.89067	4.07	16.5649	2.01742	6.37966
2.88	8.2944	1.69706	5.36656	3.48	12.1104	1.86548	5.89915	4.08	16.6464	2.01990	6.38749
2.89	8.3521	1.70000	5.37587	3.49	12.1801	1.86815	5.90762	4.09	16.7281	2.02237	6.39531
2.90	8.4100	1.70294	5.38516	**3.50**	12.2500	1.87083	5.91608	**4.10**	16.8100	2.02485	6.40312
2.91	8.4681	1.70587	5.39444	3.51	12.3201	1.87350	5.92453	4.11	16.8921	2.02731	6.41093
2.92	8.5264	1.70880	5.40370	3.52	12.3904	1.87617	5.93296	4.12	16.9744	2.02978	6.41872
2.93	8.5849	1.71172	5.41295	3.53	12.4609	1.87883	5.94138	4.13	17.0569	2.03224	6.42651
2.94	8.6436	1.71464	5.42218	3.54	12.5316	1.88149	5.94979	4.14	17.1396	2.03470	6.43428
2.95	8.7025	1.71756	5.43139	**3.55**	12.6025	1.88414	5.95819	**4.15**	17.2225	2.03715	6.44205
2.96	8.7616	1.72047	5.44059	3.56	12.6736	1.88680	5.96657	4.16	17.3056	2.03961	6.44981
2.97	8.8209	1.72337	5.44977	3.57	12.7449	1.88944	5.97495	4.17	17.3889	2.04206	6.45755
2.98	8.8804	1.72627	5.45894	3.58	12.8164	1.89209	5.98331	4.18	17.4724	2.04450	6.46529
2.99	8.9401	1.72916	5.46809	3.59	12.8881	1.89473	5.99166	4.19	17.5561	2.04695	6.47302
3.00	9.0000	1.73205	5.47723	**3.60**	12.9600	1.89737	6.00000	**4.20**	17.6400	2.04939	6.48074
3.01	9.0601	1.73494	5.48635	3.61	13.0321	1.90000	6.00833	4.21	17.7241	2.05183	6.48845
3.02	9.1204	1.73781	5.49545	3.62	13.1044	1.90263	6.01664	4.22	17.8084	2.05426	6.49615
3.03	9.1809	1.74069	5.50454	3.63	13.1769	1.90526	6.02495	4.23	17.8929	2.05670	6.50384
3.04	9.2416	1.74356	5.51362	3.64	13.2496	1.90788	6.03324	4.24	17.9776	2.05913	6.51153
3.05	9.3025	1.74642	5.52268	**3.65**	13.3225	1.91050	6.04152	**4.25**	18.0625	2.06155	6.51920
3.06	9.3636	1.74929	5.53173	3.66	13.3956	1.91311	6.04979	4.26	18.1476	2.06398	6.52687
3.07	9.4249	1.75214	5.54076	3.67	13.4689	1.91572	6.05805	4.27	18.2329	2.06640	6.53452
3.08	9.4864	1.75499	5.54977	3.68	13.5424	1.91833	6.06630	4.28	18.3184	2.06882	6.54217
3.09	9.5481	1.75784	5.55878	3.69	13.6161	1.92094	6.07454	4.29	18.4041	2.07123	6.54981
3.10	9.6100	1.76068	5.56776	**3.70**	13.6900	1.92354	6.08276	**4.30**	18.4900	2.07364	6.55744
3.11	9.6721	1.76352	5.57674	3.71	13.7641	1.92614	6.09098	4.31	18.5761	2.07605	6.56506
3.12	9.7344	1.76635	5.58570	3.72	13.8384	1.92873	6.09918	4.32	18.6624	2.07846	6.57267
3.13	9.7969	1.76918	5.59464	3.73	13.9129	1.93132	6.10737	4.33	18.7489	2.08087	6.58027
3.14	9.8596	1.77200	5.60357	3.74	13.9876	1.93391	6.11555	4.34	18.8356	2.08327	6.58787
3.15	9.9225	1.77482	5.61249	**3.75**	14.0625	1.93649	6.12372	**4.35**	18.9225	2.08567	6.59545
3.16	9.9856	1.77764	5.62139	3.76	14.1376	1.93907	6.13188	4.36	19.0096	2.08806	6.60303
3.17	10.0489	1.78045	5.63028	3.77	14.2129	1.94165	6.14003	4.37	19.0969	2.09045	6.61060
3.18	10.1124	1.78326	5.63915	3.78	14.2884	1.94422	6.14817	4.38	19.1844	2.09284	6.61816
8.19	10.1761	1.78606	5.64801	3.79	14.3641	1.94679	6.15630	4.39	19.2721	2.09523	6.62571
3.20	10.2400	1.78885	5.65685	**3.80**	14.4400	1.94936	6.16441	**4.40**	19.3600	2.09762	6.63325
3.21	10.3041	1.79165	5.66569	3.81	14.5161	1.95192	6.17252	4.41	19.4481	2.10000	6.64078
3.22	10.3684	1.79444	5.67450	3.82	14.5924	1.95448	6.18061	4.42	19.5364	2.10238	6.64831
3.23	10.4329	1.79722	5.68331	3.83	14.6689	1.95704	6.18870	4.43	19.6249	2.10476	6.65582
3.24	10.4976	1.80000	5.69210	3.84	14.7456	1.95959	6.19677	4.44	19.7136	2.10713	6.66333
3.25	10.5625	1.80278	5.70088	**3.85**	14.8225	1.96214	6.20484	**4.45**	19.8025	2.10950	6.67083
3.26	10.6276	1.80555	5.70964	3.86	14.8996	1.96469	6.21289	4.46	19.8916	2.11187	6.67832
3.27	10.6929	1.80831	5.71839	3.87	14.9769	1.96723	6.22093	4.47	19.9809	2.11424	6.68581
3.28	10.7584	1.81108	5.72713	3.88	15.0544	1.96977	6.22896	4.48	20.0704	2.11660	6.69328
3.29	10.8241	1.81384	5.73585	3.89	15.1321	1.97231	6.23699	4.49	20.1601	2.11896	6.70075
3.30	10.8900	1.81659	5.74456	**3.90**	15.2100	1.97484	6.24500	**4.50**	20.2500	2.12132	6.70820
3.31	10.9561	1.81934	5.75326	3.91	15.2881	1.97737	6.25300	4.51	20.3401	2.12368	6.71565
3.32	11.0224	1.82209	5.76194	3.92	15.3664	1.97990	6.26099	4.52	20.4304	2.12603	6.72309
3.33	11.0889	1.82483	5.77062	3.93	15.4449	1.98242	6.26897	4.53	20.5209	2.12838	6.73053
3.34	11.1556	1.82757	5.77927	3.94	15.5236	1.98494	6.27694	4.54	20.6116	2.13073	6.73795
3.35	11.2225	1.83030	5.78792	**3.95**	15.6025	1.98746	6.28490	**4.55**	20.7025	2.13307	6.74537
3.36	11.2896	1.83303	5.79655	3.96	15.6816	1.98997	6.29285	4.56	20.7936	2.13542	6.75278
3.37	11.3569	1.83576	5.80517	3.97	15.7609	1.99249	6.30079	4.57	20.8849	2.13776	6.76018
3.38	11.4244	1.83848	5.81378	3.98	15.8404	1.99499	6.30872	4.58	20.9764	2.14009	6.76757
3.39	11.4921	1.84120	5.82237	3.99	15.9201	1.99750	6.31664	4.59	21.0681	2.14243	6.77495
3.40	11.5600	1.84391	5.83095	**4.00**	16.0000	2.00000	6.32456	**4.60**	21.1600	2.14476	6.78233
N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$

SQUARES AND SQUARE ROOTS

N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$
4.60	21.1600	2.14476	6.78233	**5.20**	27.0400	2.28035	7.21110	**5.80**	33.6400	2.40832	7.61577
4.61	21.2521	2.14709	6.78970	5.21	27.1441	2.28254	7.21803	5.81	33.7561	2.41039	7.62234
4.62	21.3444	2.14942	6.79706	5.22	27.2484	2.28473	7.22496	5.82	33.8724	2.41247	7.62889
4.63	21.4369	2.15174	6.80441	5.23	27.3529	2.28692	7.23187	5.83	33.9889	2.41454	7.63544
4.64	21.5296	2.15407	6.81175	5.24	27.4576	2.28910	7.23878	5.84	34.1056	2.41661	7.64199
4.65	21.6225	2.15639	6.81909	**5.25**	27.5625	2.29129	7.24569	**5.85**	34.2225	2.41868	7.64853
4.66	21.7156	2.15870	6.82642	5.26	27.6676	2.29347	7.25259	5.86	34.3396	2.42074	7.65506
4.67	21.8089	2.16102	6.83374	5.27	27.7729	2.29565	7.25948	5.87	34.4569	2.42281	7.66159
4.68	21.9024	2.16333	6.84105	5.28	27.8784	2.29783	7.26636	5.88	34.5744	2.42487	7.66812
4.69	21.9961	2.16564	6.84836	5.29	27.9841	2.30000	7.27324	5.89	34.6921	2.42693	7.67463
4.70	22.0900	2.16795	6.85565	**5.30**	28.0900	2.30217	7.28011	**5.90**	34.8100	2.42899	7.68115
4.71	22.1841	2.17025	6.86294	5.31	28.1961	2.30434	7.28697	5.91	34.9281	2.43105	7.68765
4.72	22.2784	2.17256	6.87023	5.32	28.3024	2.30651	7.29383	5.92	35.0464	2.43311	7.69415
4.73	22.3729	2.17486	6.87750	5.33	28.4089	2.30868	7.30068	5.93	35.1649	2.43516	7.70065
4.74	22.4676	2.17715	6.88477	5.34	28.5156	2.31084	7.30753	5.94	35.2836	2.43721	7.70714
4.75	22.5625	2.17945	6.89202	**5.35**	28.6225	2.31301	7.31437	**5.95**	35.4025	2.43926	7.71362
4.76	22.6576	2.18174	6.89928	5.36	28.7296	2.31517	7.32120	5.96	35.5216	2.44131	7.72010
4.77	22.7529	2.18403	6.90652	5.37	28.8369	2.31733	7.32803	5.97	35.6409	2.44336	7.72658
4.78	22.8484	2.18632	6.91375	5.38	28.9444	2.31948	7.33485	5.98	35.7604	2.44540	7.73305
4.79	22.9441	2.18861	6.92098	5.39	29.0521	2.32164	7.34166	5.99	35.8801	2.44745	7.73951
4.80	23.0400	2.19089	6.92820	**5.40**	29.1600	2.32379	7.34847	**6.00**	36.0000	2.44949	7.74597
4.81	23.1361	2.19317	6.93542	5.41	29.2681	2.32594	7.35527	6.01	36.1201	2.45153	7.75242
4.82	23.2324	2.19545	6.94262	5.42	29.3764	2.32809	7.36206	6.02	36.2404	2.45357	7.75887
4.83	23.3289	2.19773	6.94982	5.43	29.4849	2.33024	7.36885	6.03	36.3609	2.45561	7.76531
4.84	23.4256	2.20000	6.95701	5.44	29.5936	2.33238	7.37564	6.04	36.4816	2.45764	7.77174
4.85	23.5225	2.20227	6.96419	**5.45**	29.7025	2.33452	7.38241	**6.05**	36.6025	2.45967	7.77817
4.86	23.6196	2.20454	6.97137	5.46	29.8116	2.33666	7.38918	6.06	36.7236	2.46171	7.78460
4.87	23.7169	2.20681	6.97854	5.47	29.9209	2.33880	7.39594	6.07	36.8449	2.46374	7.79102
4.88	23.8144	2.20907	6.98570	5.48	30.0304	2.34094	7.40270	6.08	36.9664	2.46577	7.79744
4.89	23.9121	2.21133	6.99285	5.49	30.1401	2.34307	7.40945	6.09	37.0881	2.46779	7.80385
4.90	24.0100	2.21359	7.00000	**5.50**	30.2500	2.34521	7.41620	**6.10**	37.2100	2.46982	7.81025
4.91	24.1081	2.21585	7.00714	5.51	30.3601	2.34734	7.42294	6.11	37.3321	2.47184	7.81665
4.92	24.2064	2.21811	7.01427	5.52	30.4704	2.34947	7.42967	6.12	37.4544	2.47386	7.82304
4.93	24.3049	2.22036	7.02140	5.53	30.5809	2.35160	7.43640	6.13	37.5769	2.47588	7.82943
4.94	24.4036	2.22261	7.02851	5.54	30.6916	2.35372	7.44312	6.14	37.6996	2.47790	7.83582
4.95	24.5025	2.22486	7.03562	**5.55**	30.8025	2.35584	7.44983	**6.15**	37.8225	2.47992	7.84219
4.96	24.6016	2.22711	7.04273	5.56	30.9136	2.35797	7.45654	6.16	37.9456	2.48193	7.84857
4.97	24.7009	2.22935	7.04982	5.57	31.0249	2.36008	7.46324	6.17	38.0689	2.48395	7.85493
4.98	24.8004	2.23159	7.05691	5.58	31.1364	2.36220	7.46994	6.18	38.1924	2.48596	7.86130
4.99	24.9001	2.23383	7.06399	5.59	31.2481	2.36432	7.47663	6.19	38.3161	2.48797	7.86766
5.00	25.0000	2.23607	7.07107	**5.60**	31.3600	2.36643	7.48331	**6.20**	38.4400	2.48998	7.87401
5.01	25.1001	2.23830	7.07814	5.61	31.4721	2.36854	7.48999	6.21	38.5641	2.49199	7.88036
5.02	25.2004	2.24054	7.08520	5.62	31.5844	2.37065	7.49667	6.22	38.6884	2.49399	7.88670
5.03	25.3009	2.24277	7.09225	5.63	31.6969	2.37276	7.50333	6.23	38.8129	2.49600	7.89303
5.04	25.4016	2.24499	7.09930	5.64	31.8096	2.37487	7.50999	6.24	38.9376	2.49800	7.89937
5.05	25.5025	2.24722	7.10634	**5.65**	31.9225	2.37697	7.51665	**6.25**	39.0625	2.50000	7.90569
5.06	25.6036	2.24944	7.11337	5.66	32.0356	2.37908	7.52330	6.26	39.1876	2.50200	7.91202
5.07	25.7049	2.25167	7.12039	5.67	32.1489	2.38118	7.52994	6.27	39.3129	2.50400	7.91833
5.08	25.8064	2.25389	7.12741	5.68	32.2624	2.38328	7.53658	6.28	39.4384	2.50599	7.92465
5.09	25.9081	2.25610	7.13442	5.69	32.3761	2.38537	7.54321	6.29	39.5641	2.50799	7.93095
5.10	26.0100	2.25832	7.14143	**5.70**	32.4900	2.38747	7.54983	**6.30**	39.6900	2.50998	7.93725
5.11	26.1121	2.26053	7.14843	5.71	32.6041	2.38956	7.55645	6.31	39.8161	2.51197	7.94355
5.12	26.2144	2.26274	7.15542	5.72	32.7184	2.39165	7.56307	6.32	39.9424	2.51396	7.94984
5.13	26.3169	2.26495	7.16240	5.73	32.8329	2.39374	7.56968	6.33	40.0689	2.51595	7.95613
5.14	26.4196	2.26716	7.16938	5.74	32.9476	2.39583	7.57628	6.34	40.1956	2.51794	7.96241
5.15	26.5225	2.26936	7.17635	**5.75**	33.0625	2.39792	7.58288	**6.35**	40.3225	2.51992	7.96869
5.16	26.6256	2.27156	7.18331	5.76	33.1776	2.40000	7.58947	6.36	40.4496	2.52190	7.97496
5.17	26.7289	2.27376	7.19027	5.77	33.2929	2.40208	7.59605	6.37	40.5769	2.52389	7.98123
5.18	26.8324	2.27596	7.19722	5.78	33.4084	2.40416	7.60263	6.38	40.7044	2.52587	7.98749
5.19	26.9361	2.27816	7.20417	5.79	33.5241	2.40624	7.60920	6.39	40.8321	2.52784	7.99375
5.20	27.0400	2.28035	7.21110	**5.80**	33.6400	2.40832	7.61577	**6.40**	40.9600	2.52982	8.00000
N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$

SQUARES AND SQUARE ROOTS

N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$
6.40	40.9600	2.52982	8.00000	**7.00**	49.0000	2.64575	8.36660	**7.60**	57.7600	2.75681	8.71780
6.41	41.0881	2.53180	8.00625	7.01	49.1401	2.64764	8.37257	7.61	57.9121	2.75862	8.72353
6.42	41.2164	2.53377	8.01249	7.02	49.2804	2.64953	8.37854	7.62	58.0644	2.76043	8.72926
6.43	41.3449	2.53574	8.01873	7.03	49.4209	2.65141	8.38451	7.63	58.2169	2.76225	8.73499
6.44	41.4736	2.53772	8.02496	7.04	49.5616	2.65330	8.39047	7.64	58.3696	2.76405	8.74071
6.45	41.6025	2.53969	8.03119	**7.05**	49.7025	2.65518	8.39643	**7.65**	58.5225	2.76586	8.74643
6.46	41.7316	2.54165	8.03741	7.06	49.8436	2.65707	8.40238	7.66	58.6756	2.76767	8.75214
6.47	41.8609	2.54362	8.04363	7.07	49.9849	2.65895	8.40833	7.67	58.8289	2.76948	8.75785
6.48	41.9904	2.54558	8.04984	7.08	50.1264	2.66083	8.41427	7.68	58.9824	2.77128	8.76356
6.49	42.1201	2.54755	8.05605	7.09	50.2681	2.66271	8.42021	7.69	59.1361	2.77308	8.76926
6.50	42.2500	2.54951	8.06226	**7.10**	50.4100	2.66458	8.42615	**7.70**	59.2900	2.77489	8.77496
6.51	42.3801	2.55147	8.06846	7.11	50.5521	2.66646	8.43208	7.71	59.4441	2.77669	8.78066
6.52	42.5104	2.55343	8.07465	7.12	50.6944	2.66833	8.43801	7.72	59.5984	2.77849	8.78635
6.53	42.6409	2.55539	8.08084	7.13	50.8369	2.67021	8.44393	7.73	59.7529	2.78029	8.79204
6.54	42.7716	2.55734	8.08703	7.14	50.9796	2.67208	8.44985	7.74	59.9076	2.78209	8.79773
6.55	42.9025	2.55930	8.09321	**7.15**	51.1225	2.67395	8.45577	**7.75**	60.0625	2.78388	8.80341
6.56	43.0336	2.56125	8.09938	7.16	51.2656	2.67582	8.46168	7.76	60.2176	2.78568	8.80909
6.57	43.1649	2.56320	8.10555	7.17	51.4089	2.67769	8.46759	7.77	60.3729	2.78747	8.81476
6.58	43.2964	2.56515	8.11172	7.18	51.5524	2.67955	8.47349	7.78	60.5284	2.78927	8.82043
6.59	43.4281	2.56710	8.11788	7.19	51.6961	2.68142	8.47939	7.79	60.6841	2.79106	8.82610
6.60	43.5600	2.56905	8.12404	**7.20**	51.8400	2.68328	8.48528	**7.80**	60.8400	2.79285	8.83176
6.61	43.6921	2.57099	8.13019	7.21	51.9841	2.68514	8.49117	7.81	60.9961	2.79464	8.83742
6.62	43.8244	2.57294	8.13634	7.22	52.1284	2.68701	8.49706	7.82	61.1524	2.79643	8.84308
6.63	43.9569	2.57488	8.14248	7.23	52.2729	2.68887	8.50294	7.83	61.3089	2.79821	8.84873
6.64	44.0896	2.57682	8.14862	7.24	52.4176	2.69072	8.50882	7.84	61.4656	2.80000	8.85438
6.65	44.2225	2.57876	8.15475	**7.25**	52.5625	2.69258	8.51469	**7.85**	61.6225	2.80179	8.86002
6.66	44.3556	2.58070	8.16088	7.26	52.7076	2.69444	8.52056	7.86	61.7796	2.80357	8.86566
6.67	44.4889	2.58263	8.16701	7.27	52.8529	2.69629	8.52643	7.87	61.9369	2.80535	8.87130
6.68	44.6224	2.58457	8.17313	7.28	52.9984	2.69815	8.53229	7.88	62.0944	2.80713	8.87694
6.69	44.7561	2.58650	8.17924	7.29	53.1441	2.70000	8.53815	7.89	62.2521	2.80891	8.88257
6.70	44.8900	2.58844	8.18535	**7.30**	53.2900	2.70185	8.54400	**7.90**	62.4100	2.81069	8.88819
6.71	45.0241	2.59037	8.19146	7.31	53.4361	2.70370	8.54985	7.91	62.5681	2.81247	8.89382
6.72	45.1584	2.59230	8.19756	7.32	53.5824	2.70555	8.55570	7.92	62.7264	2.81425	8.89944
6.73	45.2929	2.59422	8.20366	7.33	53.7289	2.70740	8.56154	7.93	62.8849	2.81603	8.90505
6.74	45.4276	2.59615	8.20975	7.34	53.8756	2.70924	8.56738	7.94	63.0436	2.81780	8.91067
6.75	45.5625	2.59808	8.21584	**7.35**	54.0225	2.71109	8.57321	**7.95**	63.2025	2.81957	8.91628
6.76	45.6976	2.60000	8.22192	7.36	54.1696	2.71293	8.57904	7.96	63.3616	2.82135	8.92188
6.77	45.8329	2.60192	8.22800	7.37	54.3169	2.71477	8.58487	7.97	63.5209	2.82312	8.92749
6.78	45.9684	2.60384	8.23408	7.38	54.4644	2.71662	8.59069	7.98	63.6804	2.82489	8.93308
6.79	46.1041	2.60576	8.24015	7.39	54.6121	2.71846	8.59651	7.99	63.8401	2.82666	8.93868
6.80	46.2400	2.60768	8.24621	**7.40**	54.7600	2.72029	8.60233	**8.00**	64.0000	2.82843	8.94427
6.81	46.3761	2.60960	8.25227	7.41	54.9081	2.72213	8.60814	8.01	64.1601	2.83019	8.94986
6.82	46.5124	2.61151	8.25833	7.42	55.0564	2.72397	8.61394	8.02	64.3204	2.83196	8.95545
6.83	46.6489	2.61343	8.26438	7.43	55.2049	2.72580	8.61974	8.03	64.4809	2.83373	8.96103
6.84	46.7856	2.61534	8.27043	7.44	55.3536	2.72764	8.62554	8.04	64.6416	2.83549	8.96660
6.85	46.9225	2.61725	8.27647	**7.45**	55.5025	2.72947	8.63134	**8.05**	64.8025	2.83725	8.97218
6.86	47.0596	2.61916	8.28251	7.46	55.6516	2.73130	8.63713	8.06	64.9636	2.83901	8.97775
6.87	47.1969	2.62107	8.28855	7.47	55.8009	2.73313	8.64292	8.07	65.1249	2.84077	8.98332
6.88	47.3344	2.62298	8.29458	7.48	55.9504	2.73496	8.64870	8.08	65.2864	2.84253	8.98888
6.89	47.4721	2.62488	8.30060	7.49	56.1001	2.73679	8.65448	8.09	65.4481	2.84429	8.99444
6.90	47.6100	2.62679	8.30662	**7.50**	56.2500	2.73861	8.66025	**8.10**	65.6100	2.84605	9.00000
6.91	47.7481	2.62869	8.31264	7.51	56.4001	2.74044	8.66603	8.11	65.7721	2.84781	9.00555
6.92	47.8864	2.63059	8.31865	7.52	56.5504	2.74226	8.67179	8.12	65.9344	2.84956	9.01110
6.93	48.0249	2.63249	8.32466	7.53	56.7009	2.74408	8.67756	8.13	66.0969	2.85132	9.01665
6.94	48.1636	2.63439	8.33067	7.54	56.8516	2.74591	8.68332	8.14	66.2596	2.85307	9.02219
6.95	48.3025	2.63629	8.33667	**7.55**	57.0025	2.74773	8.68907	**8.15**	66.4225	2.85482	9.02774
6.96	48.4416	2.63818	8.34266	7.56	57.1536	2.74955	8.69483	8.16	66.5856	2.85657	9.03327
6.97	48.5809	2.64008	8.34865	7.57	57.3049	2.75136	8.70057	8.17	66.7489	2.85832	9.03881
6.98	48.7204	2.64197	8.35464	7.58	57.4564	2.75318	8.70632	8.18	66.9124	2.86007	9.04434
6.99	48.8601	2.64386	8.36062	7.59	57.6081	2.75500	8.71206	8.19	67.0761	2.86182	9.04986
7.00	49.0000	2.64575	8.36660	**7.60**	57.7600	2.75681	8.71780	**8.20**	67.2400	2.86356	9.05539
N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$

SQUARES AND SQUARE ROOTS

N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$
8.20	67.2400	2.86356	9.05539	**8.80**	77.4400	2.96648	9.38083	**9.40**	88.3600	3.06594	9.69536
8.21	67.4041	2.86531	9.06091	8.81	77.6161	2.96816	9.38616	9.41	88.5481	3.06757	9.70052
8.22	67.5684	2.86705	9.06642	8.82	77.7924	2.96985	9.39149	9.42	88.7364	3.06920	9.70567
8.23	67.7329	2.86880	9.07193	8.83	77.9689	2.97153	9.39681	9.43	88.9249	3.07083	9.71082
8.24	67.8976	2.87054	9.07744	8.84	78.1456	2.97321	9.40213	9.44	89.1136	3.07246	9.71597
8.25	68.0625	2.87228	9.08295	**8.85**	78.3225	2.97489	9.40744	**9.45**	89.3025	3.07409	9.72111
8.26	68.2276	2.87402	9.08845	8.86	78.4996	2.97658	9.41276	9.46	89.4916	3.07571	9.72625
8.27	68.3929	2.87576	9.09395	8.87	78.6769	2.97825	9.41807	9.47	89.6809	3.07734	9.73139
8.28	68.5584	2.87750	9.09945	8.88	78.8544	2.97993	9.42338	9.48	89.8704	3.07896	9.73653
8.29	68.7241	2.87924	9.10494	8.89	79.0321	2.98161	9.42868	9.49	90.0601	3.08058	9.74166
8.30	68.8900	2.88097	9.11043	**8.90**	79.2100	2.98329	9.43398	**9.50**	90.2500	3.08221	9.74679
8.31	69.0561	2.88271	9.11592	8.91	79.3881	2.98496	9.43928	9.51	90.4401	3.08383	9.75192
8.32	69.2224	2.88444	9.12140	8.92	79.5664	2.98664	9.44458	9.52	90.6304	3.08545	9.75705
8.33	69.3889	2.88617	9.12688	8.93	79.7449	2.98831	9.44987	9.53	90.8209	3.08707	9.76217
8.34	69.5556	2.88791	9.13236	8.94	79.9236	2.98998	9.45516	9.54	91.0116	3.08869	9.76729
8.35	69.7225	2.88964	9.13783	**8.95**	80.1025	2.99166	9.46044	**9.55**	91.2025	3.09031	9.77241
8.36	69.8896	2.89137	9.14330	8.96	80.2816	2.99333	9.46573	9.56	91.3936	3.09192	9.77753
8.37	70.0569	2.89310	9.14877	8.97	80.4609	2.99500	9.47101	9.57	91.5849	3.09354	9.78264
8.38	70.2244	2.89482	9.15423	8.98	80.6404	2.99666	9.47629	9.58	91.7764	3.09516	9.78775
8.39	70.3921	2.89655	9.15969	8.99	80.8201	2.99833	9.48156	9.59	91.9681	3.09677	9.79285
8.40	70.5600	2.89828	9.16515	**9.00**	81.0000	3.00000	9.48683	**9.60**	92.1600	3.09839	9.79796
8.41	70.7281	2.90000	9.17061	9.01	81.1801	3.00167	9.49210	9.61	92.3521	3.10000	9.80306
8.42	70.8964	2.90172	9.17606	9.02	81.3604	3.00333	9.49737	9.62	92.5444	3.10161	9.80816
8.43	71.0649	2.90345	9.18150	9.03	81.5409	3.00500	9.50263	9.63	92.7369	3.10322	9.81326
8.44	71.2336	2.90517	9.18695	9.04	81.7216	3.00666	9.50789	9.64	92.9296	3.10483	9.81835
8.45	71.4025	2.90689	9.19239	**9.05**	81.9025	3.00832	9.51315	**9.65**	93.1225	3.10644	9.82344
8.46	71.5716	2.90861	9.19783	9.06	82.0836	3.00998	9.51840	9.66	93.3156	3.10805	9.82853
8.47	71.7409	2.91033	9.20326	9.07	82.2649	3.01164	9.52365	9.67	93.5089	3.10966	9.83362
8.48	71.9104	2.91204	9.20869	9.08	82.4464	3.01330	9.52890	9.68	93.7024	3.11127	9.83870
8.49	72.0801	2.91376	9.21412	9.09	82.6281	3.01496	9.53415	9.69	93.8961	3.11288	9.84378
8.50	72.2500	2.91548	9.21954	**9.10**	82.8100	3.01662	9.53939	**9.70**	94.0900	3.11448	9.84886
8.51	72.4201	2.91719	9.22497	9.11	82.9921	3.01828	9.54463	9.71	94.2841	3.11609	9.85393
8.52	72.5904	2.91890	9.23038	9.12	83.1744	3.01993	9.54987	9.72	94.4784	3.11769	9.85901
8.53	72.7609	2.92062	9.23580	9.13	83.3569	3.02159	9.55510	9.73	94.6729	3.11929	9.86408
8.54	72.9316	2.92233	9.24121	9.14	83.5396	3.02324	9.56033	9.74	94.8676	3.12090	9.86914
8.55	73.1025	2.92404	9.24662	**9.15**	83.7225	3.02490	9.56556	**9.75**	95.0625	3.12250	9.87421
8.56	73.2736	2.92575	9.25203	9.16	83.9056	3.02655	9.57079	9.76	95.2576	3.12410	9.87927
8.57	73.4449	2.92746	9.25743	9.17	84.0889	3.02820	9.57601	9.77	95.4529	3.12570	9.88433
8.58	73.6164	2.92916	9.26283	9.18	84.2724	3.02985	9.58123	9.78	95.6484	3.12730	9.88939
8.59	73.7881	2.93087	9.26823	9.19	84.4561	3.03150	9.58645	9.79	95.8441	3.12890	9.89444
8.60	73.9600	2.93258	9.27362	**9.20**	84.6400	3.03315	9.59166	**9.80**	96.0400	3.13050	9.89949
8.61	74.1321	2.93428	9.27901	9.21	84.8241	3.03480	9.59687	9.81	96.2361	3.13209	9.90454
8.62	74.3044	2.93598	9.28440	9.22	85.0084	3.03645	9.60208	9.82	96.4324	3.13369	9.90959
8.63	74.4769	2.93769	9.28978	9.23	85.1929	3.03809	9.60729	9.83	96.6289	3.13528	9.91464
8.64	74.6496	2.93939	9.29516	9.24	85.3776	3.03974	9.61249	9.84	96.8256	3.13688	9.91968
8.65	74.8225	2.94109	9.30054	**9.25**	85.5625	3.04138	9.61769	**9.85**	97.0225	3.13847	9.92472
8.66	74.9956	2.94279	9.30591	9.26	85.7476	3.04302	9.62289	9.86	97.2196	3.14006	9.92975
8.67	75.1689	2.94449	9.31128	9.27	85.9329	3.04467	9.62808	9.87	97.4169	3.14166	9.93479
8.68	75.3424	2.94618	9.31665	9.28	86.1184	3.04631	9.63328	9.88	97.6144	3.14325	9.93982
8.69	75.5161	2.94788	9.32202	9.29	86.3041	3.04795	9.63846	9.89	97.8121	3.14484	9.94485
8.70	75.6900	2.94958	9.32738	**9.30**	86.4900	3.04959	9.64365	**9.90**	98.0100	3.14643	9.94987
8.71	75.8641	2.95127	9.33274	9.31	86.6761	3.05123	9.64883	9.91	98.2081	3.14802	9.95490
8.72	76.0384	2.95296	9.33809	9.32	86.8624	3.05287	9.65401	9.92	98.4064	3.14960	9.95992
8.73	76.2129	2.95466	9.34345	9.33	87.0489	3.05450	9.65919	9.93	98.6049	3.15119	9.96494
8.74	76.3876	2.95635	9.34880	9.34	87.2356	3.05614	9.66437	9.94	98.8036	3.15278	9.96995
8.75	76.5625	2.95804	9.35414	**9.35**	87.4225	3.05778	9.66954	**9.95**	99.0025	3.15436	9.97497
8.76	76.7376	2.95973	9.35949	9.36	87.6096	3.05941	9.67471	9.96	99.2016	3.15595	9.97998
8.77	76.9129	2.96142	9.36483	9.37	87.7969	3.06105	9.67988	9.97	99.4009	3.15753	9.98499
8.78	77.0884	2.96311	9.37017	9.38	87.9844	3.06268	9.68504	9.98	99.6004	3.15911	9.98999
8.79	77.2641	2.96479	9.37550	9.39	88.1721	3.06431	9.69020	9.99	99.8001	3.16070	9.99500
8.80	77.4400	2.96648	9.38083	**9.40**	88.3600	3.06594	9.69536	**10.00**	100.000	3.16228	10.0000
N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$	N	N^2	$\sqrt{N}$	$\sqrt{10N}$

VALUES AND LOGARITHMS OF EXPONENTIAL FUNCTIONS

Note: If $0 < x < .01$ the value for e^{-x} can be found by the use of $(1-x)$ or the value for e^{x} can be found by the use of $(1 + x)$.

x	e^{x}		e^{-x}	x	e^{x}		e^{-x}
	Value	Log_{10}	Value		Value	Log_{10}	Value
0.00	1.0000	.00000	1.00000	0.50	1.6487	.21715	.60653
0.01	1.0101	.00434	.99005	0.51	1.6653	.22149	.60050
0.02	1.0202	.00869	.98020	0.52	1.6820	.22583	.59452
0.03	1.0305	.01303	.97045	0.53	1.6989	.23018	.58860
0.04	1.0408	.01737	.96079	0.54	1.7160	.23452	.58275
0.05	1.0513	.02171	.95123	0.55	1.7333	.23886	.57695
0.06	1.0618	.02606	.94176	0.56	1.7507	.24320	.57121
0.07	1.0725	.03040	.93239	0.57	1.7683	.24755	.56553
0.08	1.0833	.03474	.92312	0.58	1.7860	.25189	.55990
0.09	1.0942	.03909	.91393	0.59	1.8040	.25623	.55433
0.10	1.1052	.04343	.90484	0.60	1.8221	.26058	.54881
0.11	1.1163	.04777	.89583	0.61	1.8404	.26492	.54335
0.12	1.1275	.05212	.88692	0.62	1.8589	.26926	.53794
0.13	1.1388	.05646	.87809	0.63	1.8776	.27361	.53259
0.14	1.1503	.06080	.86936	0.64	1.8965	.27795	.52729
0.15	1.1618	.06514	.86071	0.65	1.9155	.28229	.52205
0.16	1.1735	.06949	.85214	0.66	1.9348	.28664	.51685
0.17	1.1853	.07383	.84366	0.67	1.9542	.29098	.51171
0.18	1.1972	.07817	.83527	0.68	1.9739	.29532	.50662
0.19	1.2092	.08252	.82696	0.69	1.9937	.29966	.50158
0.20	1.2214	.08686	.81873	0.70	2.0138	.30401	.49659
0.21	1.2337	.09120	.81058	0.71	2.0340	.30835	.49164
0.22	1.2461	.09554	.80252	0.72	2.0544	.31269	.48675
0.23	1.2586	.09989	.79453	0.73	2.0751	.31703	.48191
0.24	1.2712	.10423	.78663	0.74	2.0959	.32133	.47711
0.25	1.2840	.10857	.77880	0.75	2.1170	.32572	.47237
0.26	1.2969	.11292	.77105	0.76	2.1383	.33006	.46767
0.27	1.3100	.11726	.76338	0.77	2.1598	.33441	.46301
0.28	1.3231	.12160	.75578	0.78	2.1815	.33875	.45841
0.29	1.3364	.12595	.74826	0.79	2.2034	.34309	.45384
0.30	1.3499	.13029	.74082	0.80	2.2255	.34744	.44933
0.31	1.3634	.13463	.73345	0.81	2.2479	.35178	.44486
0.32	1.3771	.13897	.72615	0.82	2.2705	.35612	.44043
0.33	1.3910	.14332	.71892	0.83	2.2933	.36046	.43605
0.34	1.4049	.14766	.71177	0.84	2.3164	.36481	.43171
0.35	1.4191	.15200	.70469	0.85	2.3396	.36915	.42741
0.36	1.4333	.15635	.69768	0.86	2.3632	.37349	.42316
0.37	1.4477	.16069	.69073	0.87	2.3869	.37784	.41895
0.38	1.4623	.16503	.68386	0.88	2.4109	.38218	.41478
0.39	1.4770	.16937	.67706	0.89	2.4351	.38652	.41066
0.40	1.4918	.17372	.67032	0.90	2.4596	.39087	.40657
0.41	1.5068	.17806	.66365	0.91	2.4843	.39521	.40252
0.42	1.5220	.18240	.65705	0.92	2.5093	.39955	.39852
0.43	1.5373	.18675	.65051	0.93	2.5345	.40389	.39455
0.44	1.5527	.19109	.64404	0.94	2.5600	.40824	.39063
0.45	1.5683	.19543	.63763	0.95	2.5857	.41258	.38674
0.46	1.5841	.19978	.63128	0.96	2.6117	.41692	.38289
0.47	1.6000	.20412	.62500	0.97	2.6379	.42127	.37908
0.48	1.6161	.20846	.61878	0.98	2.6645	.42561	.37531
0.49	1.6323	.21280	.61263	0.99	2.6912	.42995	.37158
0.50	1.6487	.21715	.60653	1.00	2.7183	.43429	.36788

x	e^x		e^{-x}	x	e^x		e^{-x}
	Value	Log_{10}	Value		Value	Log_{10}	Value
1.00	2.7183	.43429	.36788	1.50	4.4817	.65144	.22313
1.01	2.7456	.43864	.36422	1.51	4.5267	.65578	.22091
1.02	2.7732	.44298	.36060	1.52	4.5722	.66013	.21871
1.03	2.8011	.44732	.35701	1.53	4.6182	.66447	.21654
1.04	2.8292	.45167	.35345	1.54	4.6646	.66881	.21438
1.05	2.8577	.45601	.34994	1.55	4.7115	.67316	.21225
1.06	2.8864	.46035	.34646	1.56	4.7588	.67750	.21014
1.07	2.9154	.46470	.34301	1.57	4.8066	.68184	.20805
1.08	2.9447	.46904	.33960	1.58	4.8550	.68619	.20598
1.09	2.9743	.47338	.33622	1.59	4.9037	.69053	.20393
1.10	3.0042	.47772	.33287	1.60	4.9530	.69487	.20190
1.11	3.0344	.48207	.32956	1.61	5.0028	.69921	.19989
1.12	3.0649	.48641	.32628	1.62	5.0531	.70356	.19790
1.13	3.0957	.49075	.32303	1.63	5.1039	.70790	.19593
1.14	3.1268	.49510	.31982	1.64	5.1552	.71224	.19398
1.15	3.1582	.49944	.31664	1.65	5.2070	.71659	.19205
1.16	3.1899	.50378	.31349	1.66	5.2593	.72093	.19014
1.17	3.2220	.50812	.31037	1.67	5.3122	.72527	.18825
1.18	3.2544	.51247	.30728	1.68	5.3656	.72961	.18637
1.19	3.2871	.51681	.30422	1.69	5.4195	.73396	.18452
1.20	3.3201	.52115	.30119	1.70	5.4739	.73830	.18268
1.21	3.3535	.52550	.29820	1.71	5.5290	.74264	.18087
1.22	3.3872	.52984	.29523	1.72	5.5845	.74699	.17907
1.23	3.4212	.53418	.29229	1.73	5.6407	.75133	.17728
1.24	3.4556	.53853	.28938	1.74	5.6973	.75567	.17552
1.25	3.4903	.54287	.28650	1.75	5.7546	.76002	.17377
1.26	3.5254	.54721	.28365	1.76	5.8124	.76436	.17204
1.27	3.5609	.55155	.28083	1.77	5.8709	.76870	.17033
1.28	3.5966	.55590	.27804	1.78	5.9299	.77304	.16864
1.29	3.6328	.56024	.27527	1.79	5.9895	.77739	.16696
1.30	3.6693	.56458	.27253	1.80	6.0496	.78173	.16530
1.31	3.7062	.56893	.26982	1.81	6.1104	.78607	.16365
1.32	3.7434	.57327	.26714	1.82	6.1719	.79042	.16203
1.33	3.7810	.57761	.26448	1.83	6.2339	.79476	.16041
1.34	3.8190	.58195	.26185	1.84	6.2965	.79910	.15882
1.35	3.8574	.58630	.25924	1.85	6.3598	.80344	.15724
1.36	3.8962	.59064	.25666	1.86	6.4237	.80779	.15567
1.37	3.9354	.59498	.25411	1.87	6.4883	.81213	.15412
1.38	3.9749	.59933	.25158	1.88	6.5535	.81647	.15259
1.39	4.0149	.60367	.24908	1.89	6.6194	.82082	.15107
1.40	4.0552	.60801	.24660	1.90	6.6859	.82516	.14957
1.41	4.0960	.61236	.24414	1.91	6.7531	.82950	.14808
1.42	4.1371	.61670	.24171	1.92	6.8210	.83385	14661
1.43	4.1787	.62104	.23931	1.93	6.8895	.83819	.14515
1.44	4.2207	.62538	.23693	1.94	6.9588	.84253	.14370
1.45	4.2631	.62973	.23457	1.95	7.0287	.84687	.14227
1.46	4.3060	.63407	.23224	1.96	7.0993	.85122	.14086
1.47	4.3492	.63841	.22993	1.97	7.1707	.85556	.13946
1.48	4.3929	.64276	.22764	1.98	7.2427	.85990	.13807
1.49	4.4371	.64710	.22537	1.99	7.3155	.86425	.13670
1.50	4.4817	.65144	.22313	2.00	7.3891	.86859	.13534

x	e^x		e^{-x}	x	e^x		e^{-x}
	Value	Log_{10}	Value		Value	Log_{10}	Value
2.00	7.3891	.86859	.13534	2.50	12.182	1.08574	.08208
2.01	7.4633	.87293	.13399	2.51	12.305	1.09008	.08127
2.02	7.5383	.87727	.13266	2.52	12.429	1.09442	.08046
2.03	7.6141	.88162	.13134	2.53	12.554	1.09877	.07966
2.04	7.6906	.88596	.13003	2.54	12.680	1.10311	.07887
2.05	7.7679	.89030	.12873	2.55	12.807	1.10745	.07808
2.06	7.8460	.89465	.12745	2.56	12.936	1.11179	.07730
2.07	7.9248	.89899	.12619	2.57	13.066	1.11614	.07654
2.08	8.0045	.90333	.12493	2.58	13.197	1.12048	.07577
2.09	8.0849	.90768	.12369	2.59	13.330	1.12482	.07502
2.10	8.1662	.91202	.12246	2.60	13.464	1.12917	.07427
2.11	8.2482	.91636	.12124	2.61	13.599	1.13351	.07353
2.12	8.3311	.92070	.12003	2.62	13.736	1.13785	.07280
2.13	8.4149	.92505	.11884	2.63	13.874	1.14219	.07208
2.14	8.4994	.92939	.11765	2.64	14.013	1.14654	.07136
2.15	8.5849	.93373	.11648	2.65	14.154	1.15088	.07065
2.16	8.6711	.93808	.11533	2.66	14.296	1.15522	.06995
2.17	8.7583	.94242	.11418	2.67	14.440	1.15957	.06925
2.18	8.8463	.94676	.11304	2.68	14.585	1.16391	.06856
2.19	8.9352	.95110	.11192	2.69	14.732	1.16825	.06788
2.20	9.0250	.95545	.11080	2.70	14.880	1.17260	.06721
2.21	9.1157	.95979	.10970	2.71	15.029	1.17694	.06654
2.22	9.2073	.96413	.10861	2.72	15.180	1.18128	.06587
2.23	9.2999	.96848	.10753	2.73	15.333	1.18562	.06522
2.24	9.3933	.97282	.10646	2.74	15.487	1.18997	.06457
2.25	9.4877	.97716	.10540	2.75	15.643	1.19431	.06393
2.26	9.5831	.98151	.10435	2.76	15.800	1.19865	.06329
2.27	9.6794	.98585	.10331	2.77	15.959	1.20300	.06266
2.28	9.7767	.99019	.10228	2.78	16.119	1.20734	.06204
2.29	9.8749	.99453	.10127	2.79	16.281	1.21168	.06142
2.30	9.9742	.99888	.10026	2.80	16.445	1.21602	.06081
2.31	10.074	1.00322	.09926	2.81	16.610	1.22037	.06020
2.32	10.176	1.00756	.09827	2.82	16.777	1.22471	.05961
2.33	10.278	1.01191	.09730	2.83	16.945	1.22905	.05901
2.34	10.381	1.01625	.09633	2.84	17.116	1.23340	.05843
2.35	10.486	1.02059	.09537	2.85	17.288	1.23774	.05784
2.36	10.591	1.02493	.09442	2.86	17.462	1.24208	.05727
2.37	10.697	1.02928	.09348	2.87	17.637	1.24643	.05670
2.38	10.805	1.03362	.09255	2.88	17.814	1.25077	.05613
2.39	10.913	1.03796	.09163	2.89	17.993	1.25511	.05558
2.40	11.023	1.04231	.09072	2.90	18.174	1.25945	.05502
2.41	11.134	1.04665	.08982	2.91	18.357	1.26380	.05448
2.42	11.246	1.05099	.08892	2.92	18.541	1.26814	.05393
2.43	11.359	1.05534	.08804	2.93	18.728	1.27248	.05340
2.44	11.473	1.05968	.08716	2.94	18.916	1.27683	.05287
2.45	11.588	1.06402	.08629	2.95	19.106	1.28117	.05234
2.46	11.705	1.06836	.08543	2.96	19.298	1.28551	.05182
2.47	11.822	1.07271	.08458	2.97	19.492	1.28985	.05130
2.48	11.941	1.07705	.08374	2.98	19.688	1.29420	.05079
2.49	12.061	1.08139	.08291	2.99	19.886	1.29854	.05029
2.50	12.182	1.08574	.08208	3.00	20.086	1.30288	.04979

x	e^x		e^{-x}
	Value	Log_{10}	Value
3.00	20.086	1.30288	.04979
3.05	21.115	1.32460	.04736
3.10	22.198	1.34631	.04505
3.15	23.336	1.36803	.04285
3.20	24.533	1.38974	.04076
3.25	25.790	1.41146	.03877
3.30	27.113	1.43317	.03688
3.35	28.503	1.45489	.03508
3.40	29.964	1.47660	.03337
3.45	31.500	1.49832	.03175
3.50	33.115	1.52003	.03020
3.55	34.813	1.54175	.02872
3.60	36.598	1.56346	.02732
3.65	38.475	1.58517	.02599
3.70	40.447	1.60689	.02472
3.75	42.521	1.62860	.02352
3.80	44.701	1.65032	.02237
3.85	46.993	1.67203	.02128
3.90	49.402	1.69375	.02024
3.95	51.935	1.71546	.01925
4.00	54.598	1.73718	.01832
4.10	60.340	1.78061	.01657
4.20	66.686	1.82404	.01500
4.30	73.700	1.86747	.01357
4.40	81.451	1.91090	.01227
4.50	90.017	1.95433	.01111
4.60	99.484	1.99775	.01005
4.70	109.95	2.04118	.00910
4.80	121.51	2.08461	.00823
4.90	134.29	2.12804	.00745
5.00	148.41	2.17147	.00674
5.10	164.02	2.21490	.00610
5.20	181.27	2.25833	.00552
5.30	200.34	2.30176	.00499
5.40	221.41	2.34519	.00452
5.50	244.69	2.38862	.00409
5.60	270.43	2.43205	.00370
5.70	298.87	2.47548	.00335
5.80	330.30	2.51891	.00303
5.90	365.04	2.56234	.00274
6.00	403.43	2.60577	.00248
6.25	518.01	2.71434	.00193
6.50	665.14	2.82291	.00150
6.75	854.06	2.93149	.00117
7.00	1096.6	3.04006	.00091
7.50	1808.0	3.25721	.00055
8.00	2981.0	3.47436	.00034
8.50	4914.8	3.69150	.00020
9.00	8103.1	3.90865	.00012
9.50	13360.	4.12580	.00007
10.00	22026.	4.34294	.00005

THREE-PLACE VALUES OF TRIGONOMETRIC FUNCTIONS AND DEGREES IN RADIAN MEASURE

Rad.	Deg.	Sin	Tan	Sec	Csc	Cot	Cos	Deg.	Rad.
.000	0°	.000	.000	1.000	——	——	1.000	90°	1.571
.017	1°	.017	.017	1.000	57.30	57.29	1.000	89°	1.553
.035	2°	.035	.035	1.001	28.65	28.64	0.999	88°	1.536
.052	3°	.052	.052	1.001	19.11	19.08	.999	87°	1.518
.070	4°	.070	.070	1.002	14.34	14.30	.998	86°	1.501
.087	5°	.087	.087	1.004	11.47	11.43	.996	85°	1.484
.105	6°	.105	.105	1.006	9.567	9.514	.995	84°	1.466
.122	7°	.122	.123	1.008	8.206	8.144	.993	83°	1.449
.140	8°	.139	.141	1.010	7.185	7.115	.990	82°	1.431
.157	9°	.156	.158	1.012	6.392	6.314	.988	81°	1.414
.175	10°	.174	.176	1.015	5.759	5.671	.985	80°	1.396
.192	11°	.191	.194	1.019	5.241	5.145	.982	79°	1.379
.209	12°	.208	.213	1.022	4.810	4.705	.978	78°	1.361
.227	13°	.225	.231	1.026	4.445	4.331	.974	77°	1.344
.244	14°	.242	.249	1.031	4.134	4.011	.970	76°	1.326
.262	15°	.259	.268	1.035	3.864	3.732	.966	75°	1.309
.279	16°	.276	.287	1.040	3.628	3.487	.961	74°	1.292
.297	17°	.292	.306	1.046	3.420	3.271	.956	73°	1.274
.314	18°	.309	.325	1.051	3.236	3.078	.951	72°	1.257
.332	19°	.326	.344	1.058	3.072	2.904	.946	71°	1.239
.349	20°	.342	.364	1.064	2.924	2.747	.940	70°	1.222
.367	21°	.358	.384	1.071	2.790	2.605	.934	69°	1.204
.384	22°	.375	.404	1.079	2.669	2.475	.927	68°	1.187
.401	23°	.391	.424	1.086	2.559	2.356	.921	67°	1.169
.419	24°	.407	.445	1.095	2.459	2.246	.914	66°	1.152
.436	25°	.423	.466	1.103	2.366	2.145	.906	65°	1.134
.454	26°	.438	.488	1.113	2.281	2.050	.899	64°	1.117
.471	27°	.454	.510	1.122	2.203	1.963	.891	63°	1.100
.489	28°	.469	.532	1.133	2.130	1.881	.883	62°	1.082
.506	29°	.485	.554	1.143	2.063	1.804	.875	61°	1.065
.524	30°	.500	.577	1.155	2.000	1.732	.866	60°	1.047
.541	31°	.515	.601	1.167	1.942	1.664	.857	59°	1.030
.559	32°	.530	.625	1.179	1.887	1.600	.848	58°	1.012
.576	33°	.545	.649	1.192	1.836	1.540	.839	57°	0.995
.593	34°	.559	.675	1.206	1.788	1.483	.829	56°	0.977
.611	35°	.574	.700	1.221	1.743	1.428	.819	55°	0.960
.628	36°	.588	.727	1.236	1.701	1.376	.809	54°	0.942
.646	37°	.602	.754	1.252	1.662	1.327	.799	53°	0.925
.663	38°	.616	.781	1.269	1.624	1.280	.788	52°	0.908
.681	39°	.629	.810	1.287	1.589	1.235	.777	51°	0.890
.698	40°	.643	.839	1.305	1.556	1.192	.766	50°	0.873
.716	41°	.656	.869	1.325	1.524	1.150	.755	49°	0.855
.733	42°	.669	.900	1.346	1.494	1.111	.743	48°	0.838
.750	43°	.682	.933	1.367	1.466	1.072	.731	47°	0.820
.768	44°	.695	0.966	1.390	1.440	1.036	.719	46°	0.803
.785	45°	.707	1.000	1.414	1.414	1.000	.707	45°	0.785
Rad.	Deg.	Cos	Cot	Csc	Sec	Tan	Sin	Deg.	Rad.

NATURAL (NAPIERIAN) LOGARITHMS

The natural logarithm of a number is the index of the power to which the base *e* (2.7182818) must be raised in order to equal the number.

Example: $\log_e 4.12 = \ln 4.12 = 1.4159$.

The table gives the natural logarithms of numbers from 1.00 to 9.99 directly, and permits finding logarithms of numbers outside that range by the addition or subtraction of the natural logarithms of powers of 10.

Example: $\ln 679. = \ln 6.79 + \ln 10^2 = 1.9155 + 4.6052 = 6.5207$

$\ln 0.0679 = \ln 6.79 - \ln 10^2 = 1.9155 - 4.6052 = -2.6897$

Natural Logarithms of 10^k

$\ln 10 = 2.302585$	$\ln 10^4 = 9.210340$	$\ln 10^7 = 16.118096$
$\ln 10^2 = 4.605170$	$\ln 10^5 = 11.512925$	$\ln 10^8 = 18.420681$
$\ln 10^3 = 6.907755$	$\ln 10^6 = 13.815511$	$\ln 10^9 = 20.723266$

To obtain the common logarithm, the natural logarithm is multiplied by $\log_{10} e$, which is 0.434294, or $\log_{10} N = 0.434294 \ln N$.

N	0	1	2	3	4	5	6	7	8	9
1.0	**0.0000**	**0.0100**	**0.0198**	**0.0296**	**0.0392**	**0.0488**	**0.0583**	**0.0677**	**0.0770**	**0.0862**
1.1	0.0953	0.1044	0.1133	0.1222	0.1310	0.1398	0.1484	0.1570	0.1655	0.1740
1.2	0.1823	0.1906	0.1989	0.2070	0.2151	0.2231	0.2311	0.2390	0.2469	0.2546
1.3	0.2624	0.2700	0.2776	0.2852	0.2927	0.3001	0.3075	0.3148	0.3221	0.3293
1.4	0.3365	0.3436	0.3507	0.3577	0.3646	0.3716	0.3784	0.3853	0.3920	0.3988
1.5	0.4055	0.4121	0.4187	0.4253	0.4313	0.4383	0.4447	0.4511	0.4574	0.4637
1.6	0.4700	0.4762	0.4824	0.4886	0.4947	0.5008	0.5068	0.5128	0.5188	0.5247
1.7	0.5306	0.5365	0.5423	0.5481	0.5539	0.5596	0.5653	0.5710	0.5766	0.5822
1.8	0.5878	0.5933	0.5988	0.6043	0.6098	0.6152	0.6206	0.6259	0.6313	0.6366
1.9	0.6419	0.6471	0.6523	0.6575	0.6627	0.6678	0.6729	0.6780	0.6831	0.6881
2.0	**0.6931**	**0.6981**	**0.7031**	**0.7080**	**0.7129**	**0.7178**	**0.7227**	**0.7275**	**0.7324**	**0.7372**
2.1	0.7419	0.7467	0.7514	0.7561	0.7608	0.7655	0.7701	0.7747	0.7793	0.7839
2.2	0.7885	0.7930	0.7975	0.8020	0.8065	0.8109	0.8154	0.8198	0.8242	0.8286
2.3	0.8329	0.8372	0.8416	0.8459	0.8502	0.8544	0.8587	0.8629	0.8671	0.8713
2.4	0.8755	0.8796	0.8838	0.8879	0.8920	0.8961	0.9002	0.9042	0.9083	0.9123
2.5	0.9163	0.9203	0.9243	0.9282	0.9322	0.9361	0.9400	0.9439	0.9478	0.9517
2.6	0.9555	0.9594	0.9632	0.9670	0.9708	0.9746	0.9783	0.9821	0.9858	0.9895
2.7	0.9933	0.9969	1.0006	1.0043	1.0080	1.0116	1.0152	1.0188	1.0225	1.0260
2.8	1.0296	1.0332	1.0367	1.0403	1.0438	1.0473	1.0508	1.0543	1.0578	1.0613
2.9	1.0647	1.0682	1.0716	1.0750	1.0784	1.0818	1.0852	1.0886	1.0919	1.0953
3.0	**1.0986**	**1.1019**	**1.1053**	**1.1086**	**1.1119**	**1.1151**	**1.1184**	**1.1217**	**1.1249**	**1.1282**
3.1	1.1314	1.1346	1.1378	1.1410	1.1442	1.1474	1.1506	1.1537	1.1569	1.1600
3.2	1.1632	1.1663	1.1694	1.1725	1.1756	1.1787	1.1817	1.1848	1.1878	1.1909
3.3	1.1939	1.1969	1.2000	1.2030	1.2060	1.2090	1.2119	1.2149	1.2179	1.2208
3.4	1.2238	1.2267	1.2296	1.2326	1.2355	1.2384	1.2413	1.2442	1.2470	1.2499
3.5	1.2528	1.2556	1.2585	1.2613	1.2641	1.2669	1.2698	1.2726	1.2754	1.2782
3.6	1.2809	1.2837	1.2865	1.2892	1.2920	1.2947	1.2975	1.3002	1.3029	1.3056
3.7	1.3083	1.3110	1.3137	1.3164	1.3191	1.3218	1.3244	1.3271	1.3297	1.3324
3.8	1.3350	1.3376	1.3403	1.3429	1.3455	1.3481	1.3507	1.3533	1.3558	1.3584
3.9	1.3610	1.3635	1.3661	1.3686	1.3712	1.3737	1.3762	1.3788	1.3813	1.3838
4.0	**1.3863**	**1.3888**	**1.3913**	**1.3938**	**1.3962**	**1.3987**	**1.4012**	**1.4036**	**1.4061**	**1.4085**
4.1	1.4110	1.4134	1.4159	1.4183	1.4207	1.4231	1.4255	1.4279	1.4303	1.4327
4.2	1.4351	1.4375	1.4398	1.4422	1.4446	1.4469	1.4493	1.4516	1.4540	1.4563
4.3	1.4586	1.4609	1.4633	1.4656	1.4679	1.4702	1.4725	1.4748	1.4770	1.4793
4.4	1.4816	1.4839	1.4861	1.4884	1.4907	1.4929	1.4951	1.4974	1.4996	1.5019
4.5	1.5041	1.5063	1.5085	1.5107	1.5129	1.5151	1.5173	1.5195	1.5217	1.5239
4.6	1.5261	1.5282	1.5304	1.5326	1.5347	1.5369	1.5390	1.5412	1.5433	1.5454
4.7	1.5476	1.5497	1.5518	1.5539	1.5560	1.5581	1.5602	1.5623	1.5644	1.5665
4.8	1.5686	1.5707	1.5728	1.5748	1.5769	1.5790	1.5810	1.5831	1.5851	1.5872
4.9	1.5892	1.5913	1.5933	1.5953	1.5974	1.5994	1.6014	1.6034	1.6054	1.6074

N	0	1	2	3	4	5	6	7	8	9
5.0	**1.6094**	**1.6114**	**1.6134**	**1.6154**	**1.6174**	**1.6194**	**1.6214**	**1.6233**	**1.6253**	**1.6273**
5.1	1.6292	1.6312	1.6332	1.6351	1.6371	1.6390	1.6409	1.6429	1.6448	1.6467
5.2	1.6487	1.6506	1.6525	1.6544	1.6563	1.6582	1.6601	1.6620	1.6639	1.6658
5.3	1.6677	1.6696	1.6715	1.6734	1.6752	1.6771	1.6790	1.6808	1.6827	1.6845
5.4	1.6864	1.6882	1.6901	1.6919	1.6938	1.6956	1.6974	1.6993	1.7011	1.7029
5.5	1.7047	1.7066	1.7084	1.7102	1.7120	1.7138	1.7156	1.7174	1.7192	1.7210
5.6	1.7228	1.7246	1.7263	1.7281	1.7299	1.7317	1.7334	1.7352	1.7370	1.7387
5.7	1.7405	1.7422	1.7440	1.7457	1.7475	1.7492	1.7509	1.7527	1.7544	1.7561
5.8	1.7579	1.7596	1.7613	1.7630	1.7647	1.7664	1.7681	1.7699	1.7716	1.7733
5.9	1.7750	1.7766	1.7783	1.7800	1.7817	1.7834	1.7851	1.7867	1.7884	1.7901
6.0	**1.7918**	**1.7934**	**1.7951**	**1.7967**	**1.7984**	**1.8001**	**1.8017**	**1.8034**	**1.8050**	**1.8066**
6.1	1.8083	1.8099	1.8116	1.8132	1.8148	1.8165	1.8181	1.8197	1.8213	1.8229
6.2	1.8245	1.8262	1.8278	1.8294	1.8310	1.8326	1.8342	1.8358	1.8374	1.8390
6.3	1.8405	1.8421	1.8437	1.8453	1.8469	1.8485	1.8500	1.8516	1.8532	1.8547
6.4	1.8563	1.8579	1.8594	1.8610	1.8625	1.8641	1.8656	1.8672	1.8687	1.8703
6.5	1.8718	1.8733	1.8749	1.8764	1.8779	1.8795	1.8810	1.8825	1.8840	1.8556
6.6	1.8871	1.8886	1.8901	1.8916	1.8931	1.8946	1.8961	1.8976	1.8991	1.9006
6.7	1.9021	1.9036	1.9051	1.9066	1.9081	1.9095	1.9110	1.9125	1.9140	1.9155
6.8	1.9169	1.9184	1.9199	1.9213	1.9228	1.9242	1.9257	1.9272	1.9286	1.9301
6.9	1.9315	1.9330	1.9344	1.9359	1.9373	1.9387	1.9402	1.9416	1.9430	1.9445
7.0	**1.9459**	**1.9473**	**1.9488**	**1.9502**	**1.9516**	**1.9530**	**1.9544**	**1.9559**	**1.9573**	**1.9587**
7.1	1.9601	1.9615	1.9629	1.9643	1.9657	1.9671	1.9685	1.9699	1.9713	1.9727
7.2	1.9741	1.9755	1.9769	1.9782	1.9796	1.9810	1.9824	1.9338	1.9851	1.9865
7.3	1.9879	1.9892	1.9906	1.9920	1.9933	1.9947	1.9961	1.9974	1.9988	2.0001
7.4	2.0015	2.0028	2.0042	2.0055	2.0069	2.0082	2.0096	2.0109	2.0122	2.0136
7.5	2.0149	2.0162	2.0176	2.0189	2.0202	2.0215	2.0229	2.0242	2.0255	2.0268
7.6	2.0281	2.0295	2.0308	2.0321	2.0334	2.0347	2.0360	2.0373	2.0386	2.0399
7.7	2.0412	2.0425	2.0438	2.0451	2.0464	2.0477	2.0490	2.0503	2.0516	2.0528
7.8	2.0541	2.0554	2 0567	2.0580	2.0592	2.0605	2.0618	2.0631	2.0643	2.0656
7.9	2.0669	2.0681	2.0694	2.0707	2.0719	2.0732	2.0744	2.0757	2.0769	2.0782
8.0	**2.0794**	**2.0807**	**2.0819**	**2.0832**	**2.0844**	**2.0857**	**2.0869**	**2.0882**	**2.0894**	**2.0906**
8.1	2.0919	2.0931	2.0943	2.0956	2.0968	2.0989	2.0992	2.1005	2.1017	2.1029
8.2	2.1041	2.1054	2.1066	2.1078	2.1090	2.1102	2.1114	2.1126	2.1138	2.1150
8.3	2.1163	2.1175	2.1187	2.1199	2.1211	2.1223	2.1235	2.1247	2.1258	2.1270
8.4	2.1282	2.1294	2.1306	2.1318	2.1330	2.1342	2.1353	2.1365	2.1377	2.1389
8.5	2.1401	2.1412	2.1424	2.1436	2.1448	2.1459	2.1471	2.1483	2.1494	2.1506
8.6	2.1518	2.1529	2.1541	2.1552	2.1564	2.1576	2.1587	2.1599	2.1610	2.1622
8.7	2.1633	2.1645	2.1656	2.1668	2.1679	2.1691	2.1702	2.1713	2.1725	2.1736
8.8	2.1748	2.1759	2.1770	2.1782	2.1793	2.1804	2.1815	2.1827	2.1838	2.1849
8.9	2.1861	2.1872	2.1883	2.1894	2.1905	2.1917	2.1928	2.1939	2.1950	2.1961
9.0	**2.1972**	**2.1983**	**2.1994**	**2.2006**	**2.2017**	**2.2028**	**2.2039**	**2.2050**	**2.2061**	**2.2072**
9.1	2.2083	2.2094	2.2105	2.2116	2.2127	2.2138	2.2148	2.2159	2.2170	2.2181
9.2	2.2192	2.2203	2.2214	2.2225	2.2235	2.2246	2.225	2.2268	2.2279	2.2289
9.3	2.2300	2.2311	2.2322	2.2332	2.2343	2.2354	2.2364	2.2375	2.2386	2.2396
9.4	2.2407	2.2418	2.2428	2.2439	2.2450	2.2460	2.2471	2.2481	2.2492	2.2502
9.5	2.2513	2.2523	2.2534	2.2544	2.2555	2.2565	2.2576	2.2586	2.2597	2.2607
9.6	2.2618	2.2628	2.2638	2.2649	2.2659	2.2670	2.2680	2.2690	2.2701	2.2711
9.7	2.2721	2.2732	2.2742	2.2752	2.2762	2.2773	2.2783	2.2793	2.2803	2.2814
9.8	2.2824	2.2834	2.2844	2.2854	2.2865	2.2875	2.2885	2.2895	2.2905	2.2915
9.9	2.2925	2.2935	2.2946	2.2956	2.2966	2.2976	2.2986	2.2996	2.3006	2.3016

LOGARITHMS TO BASE 10

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	16	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	4	5	7	9	10	12	14	16
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	12	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	5	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	7	8	9	11	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	2	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	4	5	6	7	8	9	11
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	6	7	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	5	6	7	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	3	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
N	0	1	2	3	4	5	6	7	8	9	1	2	2	4	5	6	7	8	9

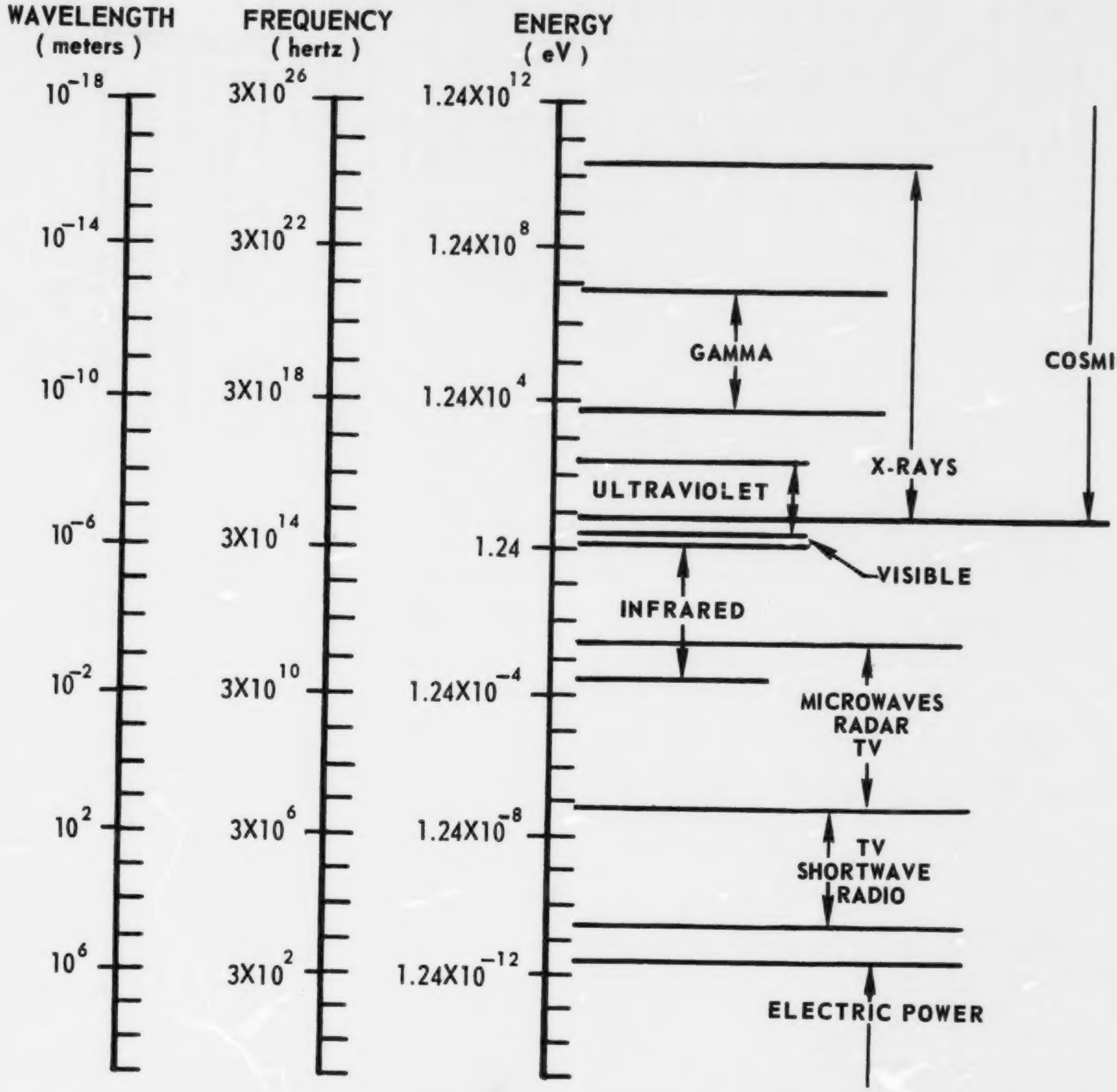
The proportional parts are stated in full for every tenth at the right-hand side. The logarithm of any number of four significant figures can be read directly by add-

(*continued*)—LOGARITHMS TO BASE 10

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	1	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	3	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	5	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	3	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	3	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	3	3	4	4	5	6
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	3	3	4	4	5	6
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	4	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	1	1	2	2	3	3	4	4	5
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	3	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4
N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9

ing the proportional part corresponding to the fourth figure to the tabular number corresponding to the first three figures. There may be an error of 1 in the last place.

THE ELECTROMAGNETIC SPECTRUM


WAVELENGTH
(meters)
10^{-18}
10^{-14}
10^{-10}
10^{-6}
10^{-2}
10^{2}
10^{6}
FREQUENCY
(hertz)
$3X10^{26}$
$3X10^{22}$
$3X10^{18}$
$3X10^{14}$
$3X10^{10}$
$3X10^{6}$
$3X10^{2}$
ENERGY
(eV)
$1.24X10^{12}$
$1.24X10^{8}$
$1.24X10^{4}$
1.24
$1.24X10^{-4}$
$1.24X10^{-8}$
$1.24X10^{-12}$
GAMMA
COSMIC
X-RAYS
ULTRAVIOLET
VISIBLE
INFRARED
MICROWAVES
RADAR
TV
TV
SHORTWAVE
RADIO
ELECTRIC POWER

Type of Radiation	Wavelength Range* (meters)	Frequency Range (hertz)	Energy Range (eV)
Electric Power	∞ - 3×10^{5}	0 - 10^{3}	0 - 4.1×10^{-12}
Radio Waves	3×10^{4} - 3×10^{-4}	10^{4} - 10^{12}	4.1×10^{-11} - 4.1×10^{-3}
Infrared	3×10^{-3} - 7.6×10^{-7}	10^{11} - 4×10^{14}	4.1×10^{-4} - 1.6
Visible	7.6×10^{-7} - 3.8×10^{-7}	4×10^{14} - 7.9×10^{14}	1.6 - 3.3
Ultraviolet	3.8×10^{-7} - 3×10^{-9}	7.9×10^{14} - 10^{17}	3.3 - 410
X Rays	1.2×10^{-7} - 4.1×10^{-17}	2.5×10^{15} - 7.3×10^{24}	10 - 3×10^{10}
Gamma Rays	1.5×10^{-10} - 1.2×10^{-13}	2×10^{18} - 2.5×10^{21}	8×10^{3} - 10^{7}
Cosmic Rays	1.2×10^{-7} - ---	2.5×10^{15} - ---	10 - ---

*Ranges are approximate; no exact end points exist.

Atomic Mass Table
(unified mass scale)

A	El.	Atomic Mass (u)	Mass Error*	Binding Energy† (MeV)
electron		0.000 549	<1	
proton		1.007 277	<1	
neutron		1.008 665	<1	
1	H	1.007 825	<1	
2	H	2.014 102	<1	2.225
3	H	3.016 050	<1	8.482
	He	3.016 030	<1	7.718
4	H	4.030 300	1830	3.280
	He	4.002 603	<1	28.296
5	H	5.031 620	1610	10.120
	He	5.012 297	20	27.338
	Li	5.012 538	40	26.331
6	He	6.018 893	4	29.266
	Li	6.015 124	1	31.993
	Be	6.019 717	13	26.932
7	Li	7.016 004	1	39.245
	Be	7.016 929	1	37.601
8	He	8.037 520	2150	28.060
	Li	8.022 487	2	41.278
	Be	8.005 308	1	56.498
	B	8.024 609	2	37.736
9	Li	9.026 802	22	45.330
	Be	9.012 186	1	58.163
	B	9.013 332	1	56.312
10	Be	10.013 534	2	64.978
	B	10.012 939	1	64.750
	C	10.016 810	14	60.361
11	Be	11.021 666	16	65.475
	B	11.009 305	<1	76.206
	C	11.011 432	1	73.443
12	B	12.014 354	1	79.575
	C	12.000 000	0	92.163
	N	12.018 641	8	74.017
13	B	13.017 780	4	84.455
	C	13.003 354	1	97.109
	N	13.005 738	1	94.106
14	C	14.003 242	<1	105.286
	N	14.003 074	<1	104.659
	O	14.008 597	<1	98.733
15	C	15.010 600	1	106.504
	N	15.000 108	1	115.494
	O	15.003 070	1	111.952
16	C	16.014 700	17	110.756
	N	16.006 103	4	117.981
	O	15.994 915	<1	127.620
	F	16.011 706	13	111.197
17	N	17.008 450	16	123.867
	O	16.999 133	1	131.763
	F	17.002 096	1	128.220
18	O	17.999 160	<1	139.809
	F	18.000 937	1	137.371
	Ne	18.005 711	5	132.142
19	O	19.003 578	3	143.765
	F	18.998 405	1	147.801
	Ne	19.001 881	2	143.781
20	O	20.004 079	9	151.370
	F	19.999 987	5	154.399
	Ne	19.992 441	1	160.646
	Na	20.008 880	320	144.550
21	F	20.999 951	8	162.504
	Ne	20.993 849	2	167.406
	Na	20.997 655	9	163.078
22	Ne	21.991 385	1	177.772
	Na	21.994 437	3	174.147
	Mg	21.999 850	90	168.320
23	Ne	22.994 473	4	182.967
	Na	22.989 771	2	186.565
	Mg	22.994 125	3	181.726

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*Errors are standard errors (one standard deviation) in the last digits of the reported atomic masses. Binding energy errors are not given, but are generally proportional to the atomic mass errors.

†Binding energies are for the entire atom and include the binding energies of the electrons.

Source: Mattauch, J.H.E., Thiele, W., Wapstra, A.H., "1964 Atomic Mass Table," Nuclear Physics, Vol. 67, No. 1 (1965), pp. 1-31.

A	El.	Atomic Mass (u)	Mass Error*	Binding Energy† (MeV)
24	Ne	23.993 613	10	191.839
	Na	23.990 962	4	193.526
	Mg	23.985 542	2	198.258
	Al	24.000 100	100	183.450
25	Na	24.989 955	9	202.535
	Mg	24.985 839	2	205.587
	Al	24.990 412	7	200.545
26	Na	25.991 740	320	208.940
	Mg	25.982 593	2	216.682
	Al	25.986 891	2	211.896
	Si	25.992 343	14	206.036
27	Mg	26.984 345	4	223.122
	Al	26.981 539	2	224.953
	Si	26.986 703	3	219.361
28	Mg	27.983 875	6	231.631
	Al	27.981 904	4	232.684
	Si	27.976 929	3	236.536
	P	27.991 780	300	221.920
29	Al	28.980 442	7	242.118
	Si	28.976 496	4	245.011
	P	28.981 808	6	239.280
30	Al	29.981 590	270	249.120
	Si	29.973 762	4	255.628
	P	29.978 317	8	250.603
	S	29.984 873	29	243.714
31	Si	30.975 349	6	262.222
	P	30.973 765	2	262.916
	S	30.979 611	12	256.688
32	Si	31.974 020	50	271.530
	P	31.973 910	2	270.852
	S	31.972 074	1	271.880
	Cl	31.986 240	410	257.800
33	P	32.971 728	4	280.955
	S	32.971 462	3	280.421
	Cl	32.977 440	13	274.070
34	P	33.973 340	210	287.530
	S	33.967 864	3	291.843
	Cl	33.973 750	6	285.578
	Ar	33.980 620	1070	278.400
35	S	34.969 031	1	298.828
	Cl	34.968 851	1	298.213
	Ar	34.975 254	18	291.467
36	S	35.967 090	9	308.707
	Cl	35.968 309	4	306.790
	Ar	35.967 545	2	306.719
	K	35.982 040	1070	292.440
37	S	36.971 010	80	313.130
	Cl	36.965 899	1	317.106
	Ar	36.966 772	1	315.510
	K	36.973 365	48	308.587
38	S	37.971 230	160	321.000
	Cl	37.968 005	9	323.216
	Ar	37.962 728	3	327.349
	K	37.969 097	10	320.634
	Ca	37.976 720	1070	312.750
39	Cl	38.968 008	20	331.284
	Ar	38.964 317	6	333.940
	K	38.963 710	3	333.723
	Ca	38.970 691	25	326.437
40	Cl	39.970 400	500	337.100
	Ar	39.962 384	1	343.812
	K	39.964 000	1	341.524
	Ca	39.962 589	4	342.056
	Sc	39.977 570	210	327.320
41	Ar	40.964 500	5	349.912
	K	40.961 832	4	351.615
	Ca	40.962 275	8	350.420
	Sc	40.969 247	10	343.143
42	Ar	41.963 048	43	359.337
	K	41.962 406	11	359.152
	Ca	41.958 625	4	361.891
	Sc	41.965 495	13	354.710
	Ti	41.974 903	16	345.164
43	K	42.960 730	12	368.784
	Ca	42.958 780	4	369.819
	Sc	42.961 165	9	366.815
	Ti	42.968 500	160	359.200
44	K	43.962 040	210	375.640
	Ca	43.955 491	4	380.954
	Sc	43.959 406	6	376.525
	Ti	43.959 572	13	375.587
45	K	44.960 680	210	384.980
	Ca	44.956 190	4	388.374
	Sc	44.955 919	3	387.843
	Ti	44.958 129	5	385.003

A	El.	Atomic Mass (u)	Mass Error*	Binding Energy† (MeV)
46	K	45.962 060	1070	391.760
	Ca	45.953 689	10	398.775
	Sc	45.955 173	4	396.611
	Ti	45.952 632	2	398.195
	V	45.960 214	10	390.350
47	K	46.961 090	320	400.740
	Ca	46.954 538	6	406.056
	Sc	46.952 413	3	407.253
	Ti	46.951 769	3	407.070
	V	46.954 899	9	403.372
48	Ca	47.952 531	10	415.996
	Sc	47.952 221	8	415.503
	Ti	47.947 950	2	418.698
	V	47.952 259	4	413.903
	Cr	47.953 760	210	411.720
49	Ca	48.955 675	12	421.140
	Sc	48.950 026	6	425.619
	Ti	48.947 870	2	426.844
	V	48.948 523	5	425.454
	Cr	48.951 271	12	422.112
50	Sc	49.951 730	210	432.100
	Ti	49.944 786	4	437.789
	V	49.947 164	4	434.791
	Cr	49.946 055	4	435.042
	Mn	49.954 215	29	426.659
51	Ti	50.946 603	7	444.168
	V	50.943 961	3	445.846
	Cr	50.944 768	3	444.312
	Mn	50.948 190	50	440.340
52	Ti	51.946 820	1070	452.040
	V	51.944 780	5	453.155
	Cr	51.940 513	3	456.347
	Mn	51.945 568	6	450.856
	Fe	51.948 117	14	447.699
53	V	52.943 980	1070	461.970
	Cr	52.940 653	3	464.288
	Mn	52.941 295	7	462.907
	Fe	52.945 572	48	458.141
54	V	53.946 720	1070	467.490
	Cr	53.938 882	4	474.009
	Mn	53.940 362	6	471.848
	Fe	53.939 617	5	471.760
	Co	53.948 475	7	462.726
55	Cr	54.940 833	7	480.263
	Mn	54.938 050	4	482.073
	Fe	54.938 299	4	481.059
	Co	54.942 013	11	476.817
56	Cr	55.940 640	160	488.520
	Mn	55.938 910	5	489.343
	Fe	55.934 936	4	492.262
	Co	55.939 847	8	486.905
	Ni	55.942 116	16	484.010
57	Mn	56.938 300	320	497.990
	Fe	56.935 398	5	499.904
	Co	56.936 296	5	498.285
	Ni	56.939 769	17	494.267
58	Mn	57.940 260	1070	504.230
	Fe	57.933 282	5	509.946
	Co	57.935 761	6	506.855
	Ni	57.935 342	5	506.462
	Cu	57.944 541	8	497.111
59	Fe	58.934 878	5	516.531
	Co	58.933 189	4	517.321
	Ni	58.934 342	4	515.465
	Cu	58.939 496	22	509.882
60	Fe	59.933 964	33	525.454
	Co	59.933 813	5	524.812
	Ni	59.930 787	5	526.848
	Cu	59.937 362	9	519.941
61	Fe	60.936 520	1070	531.140
	Co	60.932 440	43	534.162
	Ni	60.931 056	7	534.669
	Cu	60.933 457	7	531.651
	Zn	60.939 250	210	525.470
62	Co	61.933 946	43	540.831
	Ni	61.928 342	5	545.269
	Cu	61.932 566	11	540.552
	Zn	61.934 380	14	538.079
63	Co	62.933 530	210	549.290
	Ni	62.929 640	5	552.108
	Cu	62.929 592	5	551.393
	Zn	62.933 206	6	547.244
	Ga	62.939 110	1070	540.960
64	Ni	63.927 958	6	561.769
	Cu	63.929 759	5	559.309
	Zn	63.929 145	5	559.099
	Ga	63.936 737	33	551.244

A	El.	Atomic Mass (u)	Mass Error*	Binding Energy† (MeV)
65	Ni	64.930 072	8	567.872
	Cu	64.927 786	6	569.219
	Zn	64.929 234	6	567.087
	Ga	64.932 733	17	563.045
	Ge	64.939 600	1070	555.860
66	Ni	65.929 085	33	576.862
	Nu	65.928.871	9	576.279
	Zn	65.926 052	6	578.123
	Ga	65.931 607	7	572.165
	Ge	65.934 800	160	568.410
67	Cu	66.927 759	13	585.386
	Zn	66.927 145	10	585.175
	Ga	66.928 216	11	583.395
	Ge	66.932 940	110	578.210
68	Cu	67.929 770	60	591.580
	Zn	67.924 857	6	595.378
	Ga	67.927 992	7	591.676
	Ge	67.928 530	1070	590.390
69	Zn	68.926 541	7	601.881
	Ga	68.925 574	4	602.000
	Ge	68.927 963	5	598.992
	As	68.932 150	320	594.310
70	Zn	69.925 334	6	611.077
	Ga	69.926 035	6	609.642
	Ge	69.924 252	2	610.520
	As	69.930 946	32	603.502
71	Zn	70.927 510	50	617.120
	Ga	70.924 706	5	618.951
	Ge	70.924 956	6	617.935
	As	70.927 113	9	615.144
	Se	70.931 840	320	609.960
72	Zn	71.926 843	10	625.814
	Ga	71.926 372	7	625.471
	Ge	71.922 082	2	628.684
	As	71.926 763	11	623.542
	Se	71.927 410	1070	622.160
73	Ga	72.925 126	43	634.702
	Ge	72.923 463	2	635.470
	As	72.923 861	32	634.316
	Se	72.926 814	34	630.783
	Br	72.931 860	1070	625.300
74	Ga	73.927 190	50	640.850
	Ge	73.921 181	2	645.667
	As	73.923 933	4	642.321
	Se	73.922 476	5	642.895
	Br	73.929 780	1070	635.310
	Kr	73.933 100	1520	631.430
75	Ge	74.922 883	20	652.152
	As	74.921 596	4	652.568
	Se	74.922 525	4	650.921
	Br	74.925 447	22	647.416
	Kr	74.930 920	1070	641.530
76	Ge	75.921 405	2	661.600
	As	75.922 397	12	659.894
	Se	75.919 207	7	662.083
	Br	75.924 180	60	656.670
	Kr	75.925 470	1080	654.690
77	Ge	76.923 600	50	667.630
	As	76.920 646	11	669.597
	Se	76.919 911	5	669.498
	Br	76.921 376	6	667.351
	Kr	76.924 480	90	663.680
78	As	77.921 900	210	676.500
	Se	77.917 314	3	679.989
	Br	77.921 150	6	675.634
	Kr	77.920 403	5	675.547
79	As	78.920 890	60	685.510
	Se	78.918 494	5	686.961
	Br	78.918 329	3	686.333
	Kr	78.920 068	6	683.930
80	As	79.922 970	210	691.650
	Se	79.916 527	3	696.865
	Br	79.918 536	4	694.212
	Kr	79.916 380	6	695.437
	Rb	79.921 900	600	689.600
81	Se	80.917 984	7	703.579
	Br	80.916 292	5	704.373
	Kr	80.916 610	110	703.290
	Rb	80.919 020	110	700.270
82	Se	81.916 707	7	712.840
	Br	81.916 802	5	711.970
	Kr	81.913 482	5	714.279
	Rb	81.917 959	33	709.327
	Sr	81.918 390	1070	708.140
83	Br	82.915 168	17	721.562
	Kr	82.914 131	5	721.746
	Rb	82.914 730	1070	720.400
	Sr	82.917 200	1520	717.320
84	Br	83.916 550	50	728.350
	Kr	83.911 503	4	732.265
	Rb	83.914 381	5	728.803
	Sr	83.913 430	4	728.906
	Y	83.920 190	110	721.820

A	El.	Atomic Mass (u)	Mass Error*	Binding Energy† (MeV)
85	Br	84.915 530	110	737.370
	Kr	84.912 523	7	739.387
	Rb	84.911 800	5	739.278
	Sr	84.912 989	33	737.388
	Y	84.916 489	34	733.346
86	Br	85.918 200	500	742.900
	Kr	85.910 616	4	749.235
	Rb	85.911 193	7	747.915
	Sr	85.909 285	5	748.910
	Y	85.914 946	18	742.854
	Zr	85.916 230	1070	740.870
87	Kr	86.913 365	10	754.745
	Rb	86.909 187	3	757.855
	Sr	86.908 892	4	757.347
	Y	86.910 740	210	754.850
	Zr	86.914 490	220	750.560
88	Kr	87.914 270	240	761.970
	Rb	87.911 270	100	763.990
	Sr	87.905 641	6	768.447
	Y	87.909 528	8	764.044
	Zr	87.910 060	1070	762.760
	Nb	87.917 790	1520	754.780
89	Kr	88.916 600	500	767.900
	Rb	88.911 650	50	771.700
	Sr	88.907 442	7	774.840
	Y	88.905 872	5	775.521
	Zr	88.908 914	6	771.905
	Nb	88.913 080	100	767.240
90	Kr	89.919 720	110	773.040
	Rb	89.914 820	110	776.820
	Sr	89.907 747	9	782.628
	Y	89.907 163	8	782.390
	Zr	89.904 700	4	783.902
	Nb	89.911 259	11	777.009
	Mo	89.913 940	110	773.730
91	Rb	90.916 070	1070	783.730
	Sr	90.910 161	16	788.451
	Y	90.907 295	12	790.338
	Zr	90.905 642	5	791.096
	Nb	90.906 860	70	789.180
	Mo	90.911 650	60	783.930
92	Rb	91.919 140	1080	788.940
	Sr	91.910 980	80	795.760
	Y	91.908 926	22	796.890
	Zr	91.905 031	3	799.736
	Nb	91.907 211	10	796.922
	Mo	91.906 810	3	796.514
	Tc	91.915 460	150	787.670

A	El.	Atomic Mass (u)	Mass Error*	Binding Energy† (MeV)
93	Sr	92.914 710	110	800.360
	Y	92.909 552	22	804.378
	Zr	92.906 450	5	806.486
	Nb	92.906 382	5	805.767
	Mo	92.906 830	14	804.566
	Tc	92.910 251	20	800.598
94	Sr	93.915 380	240	807.800
	Y	93.911 680	210	810.470
	Zr	93.906 313	4	814.684
	Nb	93.907 303	15	812.980
	Mo	93.905 090	3	814.259
	Tc	93.909 663	7	809.216
95	Y	94.912 540	1070	817.730
	Zr	94.908 035	5	821.152
	Nb	94.906 832	3	821.490
	Mo	94.905 839	3	821.633
	Tc	94.907 620	23	819.191
	Ru	94.909 801	40	816.377
96	Y	95.915 690	1070	822.870
	Zr	95.908 286	5	828.990
	Nb	95.908 056	27	828.422
	Mo	95.904 674	3	830.789
	Tc	95.907 830	50	827.070
	Ru	95.907 598	6	826.501
97	Zr	96.910 966	23	834.565
	Nb	96.908 096	8	836.455
	Mo	96.906 022	3	837.606
	Tc	96.906 340	1070	836.520
	Ru	96.907 630	1520	834.540
	Rh	96.911 380	1520	830.270
98	Zr	97.911 960	1520	841.710
	Nb	97.910 350	1070	842.430
	Mo	97.905 409	3	846.248
	Tc	97.907 110	210	843.880
	Ru	97.905 289	4	844.795
	Rh	97.909 800	320	839.810
99	Nb	98.911 050	1070	849.850
	Mo	98.907 720	10	852.166
	Tc	98.906 249	6	852.754
	Ru	98.905 936	4	852.264
	Rh	98.908 190	22	849.381
	Pd	98.912 270	220	844.800
100	Nb	99.914 020	1070	855.150
	Mo	99.907 475	4	860.466
	Tc	99.907 840	60	859.350
	Ru	99.904 218	5	861.935
	Rh	99.908 126	22	857.512
	Pd	99.908 770	1070	856.130

A	El.	Atomic Mass (u)	Mass Error*	Binding Energy† (MeV)
101	Mo	100.910 353	20	865.857
	Tc	100.907 326	27	867.893
	Ru	100.905 577	3	868.741
	Rh	100.906 178	19	867.398
	Pd	100.908 070	60	864.860
102	Mo	101.910 250	1520	874.020
	Tc	101.909 180	1070	874.240
	Ru	101.904 348	5	877.957
	Rh	101.906 842	9	874.851
	Pd	101.905 609	11	875.217
	Ag	101.911 300	1070	869.130
103	Tc	102.908 830	110	882.640
	Ru	102.906 306	21	884.204
	Rh	102.905 511	5	884.162
	Pd	102.906 107	22	882.825
	Ag	102.908 890	110	879.450
104	Tc	103.911 710	110	888.020
	Ru	103.905 430	5	893.092
	Rh	103.906 659	7	891.164
	Pd	103.904 011	11	892.848
	Ag	103.908 596	16	887.796
	Cd	103.909 880	1070	885.810
105	Tc	104.911 330	220	896.450
	Ru	104.907 679	17	899.068
	Rh	104.905 671	13	900.156
	Pd	104.905 064	12	899.939
	Ag	104.906 460	1070	897.860
	Cd	104.909 470	1520	894.270
106	Ru	105.907 322	12	907.472
	Rh	105.907 279	12	906.729
	Pd	105.903 479	6	909.487
	Ag	105.906 661	9	905.740
	Cd	105.906 463	4	905.143
	In	105.913 440	320	897.860
107	Ru	106.910 130	320	912.920
	Rh	106.906 753	43	915.292
	Pd	106.905 132	5	916.019
	Ag	106.905 094	5	915.272
	Cd	106.906 615	6	913.072
	In	106.910 360	160	908.800
108	Ru	107.910 100	700	921.000
	Rh	107.908 700	600	921.500
	Pd	107.903 891	8	925.246
	Ag	107.905 949	8	922.547
	Cd	107.904 187	4	923.406
	In	107.909 720	90	917.470
109	Rh	108.908 640	1070	929.680
	Pd	108.905 954	5	931.396
109	Ag	108.904 756	5	931.729
	Cd	108.904 928	7	930.787
	In	108.907 096	13	927.985
110	Rh	109.911 100	500	935.500
	Pd	109.905 164	14	940.204
	Ag	109.906 095	7	938.553
	Cd	109.903 012	4	940.643
	In	109.907 231	43	935.931
111	Pd	110.907 670	50	945.940
	Ag	110.905 316	11	947.351
	Cd	110.904 188	4	947.618
	In	110.905 360	210	945.750
	Sn	110.908 060	220	942.440
112	Pd	111.907 386	33	954.276
	Ag	111.907 064	25	953.794
	Cd	111.902 763	3	957.018
	In	111.905 544	10	953.645
	Sn	111.904 835	10	953.523
113	Ag	112.906 556	43	962.339
	Cd	112.904 409	4	963.556
	In	112.904 089	9	963.071
	Sn	112.905 187	18	961.266
	Sb	112.909 986	47	956.914
114	Ag	113.908 300	430	968.790
	Cd	113.903 360	3	972.604
	In	113.904 905	9	970.383
	Sn	113.902 773	9	971.587
	Sb	113.909 510	210	964.520
115	Ag	114.908 930	180	976.270
	Cd	114.905 431	10	978.747
	In	114.903 871	8	979.417
	Sn	114.903 346	7	979.124
	Sb	114.906 599	23	975.311
116	Ag	115.911 310	1070	982.120
	Cd	115.904 762	3	987.442
	In	115.905 317	26	986.142
	Sn	115.901 745	5	988.687
	Sb	115.906 630	50	983.350
	Te	115.908 300	120	981.010
117	Cd	116.907 239	15	993.205
	In	116.904 534	10	994.943
	Sn	116.902 958	3	995.628
	Sb	116.904 912	32	993.026
	Te	116.908 670	60	988.740
118	Cd	117.906 970	1160	1 001.520
	In	117.906 110	430	1 001.540
	Sn	117.901 606	4	1 004.959

A	El.	Atomic Mass (u)	Mass Error*	Binding Energy† (MeV)
118	Sb	117.905 574	8	1 000.481
	Te	117.905 900	1070	999.400
119	Cd	118.909 740	350	1 007.020
	In	118.905 990	130	1 009.730
	Sn	118.903 313	3	1 011.440
	Sb	118.903 935	22	1 010.079
	Te	118.906 398	22	1 007.002
120	In	119.908 000	1070	1 015.930
	Sn	119.902 198	4	1 020.550
	Sb	119.905 081	8	1 017.082
	Te	119.904 023	14	1 017.285
	I	119.909 820	1070	1 011.100
121	In	120.908 090	1070	1 023.910
	Sn	120.904 227	6	1 026.732
	Sb	120.903 816	3	1 026.332
	Te	120.905 199	48	1 024.262
	I	120.907 730	70	1 021.120
	Xe	120.911 800	130	1 016.550
122	In	121.910 600	900	1 029.600
	Sn	121.903 441	4	1 035.536
	Sb	121.905 183	7	1 033.130
	Te	121.903 066	6	1 034.320
	I	121.907 511	43	1 029.397
123	In	122.910 570	1070	1 037.750
	Sn	122.905 738	11	1 041.467
	Sb	122.904 213	3	1 042.106
	Te	122.904 277	6	1 041.263
	I	122.905 730	1070	1 039.130
	Xe	122.908 730	1080	1 035.550
124	In	123.913 200	500	1 043.400
	Sn	123.905 272	5	1 049.973
	Sb	123.905 973	6	1 048.539
	Te	123.902 842	6	1 050.671
	I	123.906 246	33	1 046.719
	Xe	123.906 120	150	1 046.050
125	Sn	124.907 746	13	1 055.740
	Sb	124.905 232	9	1 057.299
	Te	124.904 418	6	1 057.275
	I	124.904 578	6	1 056.343
	Xe	124.906 620	1070	1 053.660
	Cs	124.909 910	1070	1 049.810
126	Sn	125.907 640	1090	1 063.910
	Sb	125.907 320	160	1 063.420
	Te	125.903 322	5	1 066.367
	I	125.905 631	7	1 063.434
	Xe	125.904 288	9	1 063.903
	Cs	125.909 440	430	1 058.320
127	Sn	126.910 260	1070	1 069.550
	Sb	126.906 927	33	1 071.863
	Te	126.905 209	9	1 072.681
	I	126.904 470	4	1 072.587
	Xe	126.905 220	380	1 071.100
	Cs	126.907 480	380	1 068.220
	Ba	126.911 340	1140	1 063.840
128	Sn	127.910 470	230	1 077.420
	Sb	127.909 070	160	1 077.940
	Te	127.904 476	6	1 081.435
	I	127.905 838	9	1 079.384
	Xe	127.903 540	6	1 080.742
	Cs	127.907 759	33	1 076.029
	Ba	127.908 510	1070	1 074.550
129	Sb	128.909 260	1070	1 085.830
	Te	128.906 575	9	1 087.551
	I	128.904 987	7	1 088.249
	Xe	128.904 784	5	1 087.655
	Cs	128.905 960	1070	1 085.770
	Ba	128.908 590	1070	1 082.540
	La	128.912 890	1520	1 077.760
130	Sb	129.912 040	1070	1 091.320
	Te	129.906 238	6	1 095.937
	I	129.906 676	33	1 094.747
	Xe	129.903 509	6	1 096.914
	Cs	129.906 720	22	1 093.141
	Ba	129.906 245	23	1 092.800
	La	129.912 260	1070	1 086.420
131	Te	130.908 575	22	1 101.832
	I	130.906 127	4	1 103.329
	Xe	130.905 085	4	1 103.517
	Cs	130.905 466	8	1 102.380
	Ba	130.906 716	18	1 100.433
	La	130.909 890	60	1 096.690
	Ce	130.915 500	360	1 090.690
132	Te	131.908 523	18	1 109.951
	I	131.907 981	7	1 109.674
	Xe	131.904 161	5	1 112.450
	Cs	131.906 393	27	1 109.588
	Ba	131.905 120	300	1 109.990
	La	131.910 300	320	1 104.390
	Ce	131.911 590	1120	1 102.400
133	I	132.907 750	70	1 117.960
	Xe	132.905 815	39	1 118.981
	Cs	132.905 355	38	1 118.626
	Ba	132.905 879	39	1 117.356
	La	132.908 240	220	1 114.370
	Ce	132.911 250	1100	1 110.790

A	El.	Atomic Mass (u)	Mass Error*	Binding Energy† (MeV)
134	I	133.909 850	60	1 124.070
	Xe	133.905 397	5	1 127.441
	Cs	133.906 823	41	1 125.331
	Ba	133.904 612	41	1 126.607
	La	133.908 660	70	1 122.050
	Ce	133.908 810	90	1 121.130
135	I	134.910 020	1080	1 131.980
	Xe	134.907 020	110	1 134.000
	Cs	134.905 770	110	1 134.380
	Ba	134.905 550	110	1 133.810
	La	134.906 890	1080	1 131.780
	Ce	134.909 140	1520	1 128.890
136	I	135.914 740	110	1 135.670
	Xe	135.907 221	6	1 141.885
	Cs	135.907 340	90	1 140.990
	Ba	135.904 300	80	1 143.040
	La	135.907 380	110	1 139.390
	Ce	135.907 100	500	1 138.880
137	Xe	136.911 100	110	1 146.340
	Cs	136.906 770	80	1 149.600
	Ba	136.905 500	80	1 149.990
	La	136.906 040	1080	1 148.710
	Ce	136.907 330	1520	1 146.730
	Pr	136.910 360	1520	1 143.120
138	Xe	137.913 810	1100	1 151.890
	Cs	137.910 800	1080	1 153.910
	Ba	137.905 000	60	1 158.530
	La	137.906 910	60	1 155.970
	Ce	137.905 830	60	1 156.200
	Pr	137.910 460	120	1 151.100
139	Xe	138.917 840	390	1 156.210
	Cs	138.912 900	330	1 160.030
	Ba	138.908 600	60	1 163.250
	La	138.906 140	50	1 164.760
	Ce	138.906 430	50	1 163.710
	Pr	138.908 580	120	1 160.920
	Nd	138.911 580	1080	1 157.340
140	Cs	139.917 110	1070	1 164.170
	Ba	139.910 565	23	1 169.491
	La	139.909 438	20	1 169.758
	Ce	139.905 392	19	1 172.745
	Pr	139.909 007	27	1 168.595
	Nd	139.909 330	1070	1 167.510
141	Ba	140.914 050	110	1 174.320
	La	140.910 828	37	1 176.535
	Ce	140.908 219	19	1 178.182
	Pr	140.907 596	18	1 177.981
	Nd	140.909 528	21	1 175.398
	Pm	140.913 410	220	1 171.000
142	Ba	141.916 350	120	1 180.250
	La	141.913 980	60	1 181.670
	Ce	141.909 140	50	1 185.393
	Pr	141.909 978	17	1 183.833
	Nd	141.907 663	16	1 185.207
	Pm	141.912 820	320	1 179.620
143	La	142.915 870	90	1 187.980
	Ce	142.912 327	19	1 190.499
	Pr	142.910 781	16	1 191.157
	Nd	142.909 779	15	1 191.307
	Pm	142.910 990	330	1 189.400
	Sm	142.914 550	90	1 185.300
144	La	143.919 600	1070	1 192.580
	Ce	143.913 591	19	1 197.393
	Pr	143.913 248	16	1 196.930
	Nd	143.910 039	15	1 199.137
	Pm	143.912 510	1070	1 196.050
	Sm	143.911 989	15	1 195.755
145	Ce	144.917 270	1070	1 202.040
	Pr	144.914 476	19	1 203.858
	Nd	144.912 538	15	1 204.881
	Pm	144.912 691	18	1 203.955
	Sm	144.913 394	18	1 202.519
	Eu	144.916 390	60	1 198.950
146	Ce	145.918 670	240	1 208.810
	Pr	145.917 590	220	1 209.020
	Nd	145.913 086	15	1 212.442
	Pm	145.914 632	28	1 210.219
	Sm	145.912 992	23	1 210.964
	Eu	145.917 138	37	1 206.320
	Gd	145.918 320	1070	1 204.440
147	Pr	146.918 800	1070	1 215.970
	Nd	146.916 074	19	1 217.729
	Pm	146.915 108	15	1 217.847
	Sm	146.914 867	15	1 217.290
	Eu	146.916 800	330	1 214.700
	Gd	146.919 170	1120	1 211.720
148	Pr	147.921 910	1070	1 221.140
	Nd	147.916 869	15	1 225.061
	Pm	147.917 421	26	1 223.764
	Sm	147.914 791	15	1 225.432
	Eu	147.918 110	60	1 221.560
	Gd	147.918 101	19	1 220.783
	Tb	147.924 130	320	1 214.380
149	Nd	148.920 122	18	1 230.102
	Pm	148.918 330	15	1 230.989
	Sm	148.917 180	14	1 231.278
	Eu	148.918 000	1070	1 229.740
	Gd	148.919 300	160	1 227.730
	Tb	148.923 350	60	1 223.180

A	El.	Atomic Mass (u)	Mass Error*	Binding Energy† (MeV)
150	Nd	149.920 915	15	1 237.435
	Pm	149.920 960	70	1 236.610
	Sm	149.917 276	14	1 239.260
	Eu	149.919 689	24	1 236.229
	Gd	149.918 605	24	1 236.457
	Tb	149.923 748	38	1 230.884
	Dy	149.925 590	1070	1 228.390
151	Nd	150.923 770	110	1 242.840
	Pm	150.921 198	22	1 244.460
	Sm	150.919 919	21	1 244.869
	Eu	150.919 838	21	1 244.162
	Gd	150.920 270	1070	1 242.980
	Tb	150.923 150	330	1 239.510
	Dy	150.926 250	1120	1 235.850
152	Pm	151.923 510	1070	1 250.370
	Sm	151.919 756	15	1 253.093
	Eu	151.921 749	15	1 250.453
	Gd	151.919 794	16	1 251.492
	Tb	151.924 280	160	1 246.530
	Dy	151.924 729	28	1 245.330
	Ho	151.931 560	330	1 238.180
153	Pm	152.924 030	110	1 257.960
	Sm	152.922 102	17	1 258.978
	Eu	152.921 242	18	1 258.997
	Gd	152.921 503	18	1 257.971
	Tb	152.923 490	1070	1 255.340
	Dy	152.925 740	160	1 252.460
	Ho	152.930 270	60	1 247.460
154	Sm	153.922 282	15	1 266.882
	Eu	153.923 053	20	1 265.382
	Gd	153.920 929	20	1 266.577
	Tb	153.924 580	1070	1 262.400
	Dy	153.924 350	60	1 261.820
	Ho	153.930 260	1080	1 255.540
	Er	153.932 760	1070	1 252.420
155	Sm	154.924 701	18	1 272.701
	Eu	154.922 930	19	1 273.568
	Gd	154.922 664	18	1 273.033
	Tb	154.923 630	1070	1 271.350
	Dy	154.925 880	1070	1 268.470
156	Sm	155.925 569	30	1 279.963
	Eu	155.924 802	25	1 279.896
	Gd	155.922 175	19	1 281.560
	Tb	155.924 750	1070	1 278.380
	Dy	155.923 930	180	1 278.360
157	Eu	156.925 390	60	1 287.420
	Gd	156.924 025	19	1 287.908
	Tb	156.924 090	22	1 287.065
	Dy	156.925 270	1070	1 285.180
158	Eu	157.927 940	220	1 293.120
	Gd	157.924 178	19	1 295.837
	Tb	157.925 464	29	1 293.857
	Dy	157.924 449	30	1 294.020
	Ho	157.928 790	31	1 289.193
159	Eu	158.928 840	220	1 300.350
	Gd	158.926 368	27	1 301.868
	Tb	158.925 351	26	1 302.033
	Dy	158.925 759	34	1 300.871
	Ho	158.927 690	1070	1 298.290
160	Eu	159.931 000	500	1 306.400
	Gd	159.927 115	20	1 309.244
	Tb	159.927 146	25	1 308.433
	Dy	159.925 202	21	1 309.461
	Ho	159.928 740	60	1 305.380
161	Gd	160.929 720	80	1 314.890
	Tb	160.927 572	21	1 316.107
	Dy	160.926 945	20	1 315.909
	Ho	160.927 800	1070	1 314.330
	Er	160.929 950	1080	1 311.540
	Tm	160.933 730	1080	1 307.240
162	Gd	161.930 880	1520	1 321.880
	Tb	161.929 810	1070	1 322.100
	Dy	161.926 803	19	1 324.113
	Ho	161.929 122	38	1 321.170
	Er	161.928 740	90	1 320.740
	Tm	161.933 990	140	1 315.070
163	Tb	162.930 560	60	1 329.470
	Dy	162.928 755	19	1 330.366
	Ho	162.928 766	22	1 329.574
	Er	162.930 065	23	1 327.581
	Tm	162.932 502	40	1 324.529
164	Tb	163.933 280	1070	1 335.010
	Dy	163.929 200	19	1 338.023
	Ho	163.930 390	41	1 336.132
	Er	163.929 287	43	1 336.377
	Tm	163.933 541	48	1 331.632
165	Dy	164.931 816	20	1 343.658
	Ho	164.930 421	21	1 344.175
	Er	164.930 819	22	1 343.021
	Tm	164.932 540	1070	1 340.640
	Yb	164.935 440	1520	1 337.160
166	Dy	165.932 807	30	1 350.806
	Ho	165.932 289	30	1 350.506
	Er	165.930 307	29	1 351.570
	Tm	165.933 510	60	1 347.810
	Yb	165.933 850	110	1 346.700

A	El.	Atomic Mass (u)	Mass Error*	Binding Energy† (MeV)
167	Ho	166.933 130	110	1 357.790
	Er	166.932 060	29	1 358.008
	Tm	166.933 030	1070	1 356.330
	Yb	166.935 130	1070	1 353.580
	Lu	166.938 390	1080	1 349.760
168	Ho	167.935 930	110	1 363.260
	Er	167.932 383	32	1 365.779
	Tm	167.934 230	50	1 363.279
	Yb	167.934 160	160	1 362.560
	Lu	167.939 090	1090	1 357.180
169	Ho	168.936 860	110	1 370.460
	Er	168.934 610	34	1 371.776
	Tm	168.934 245	34	1 371.334
	Yb	168.935 530	1070	1 369.350
	Lu	168.937 960	1080	1 366.310
170	Ho	169.940 070	130	1 375.540
	Er	169.935 560	70	1 378.960
	Tm	169.936 060	60	1 377.720
	Yb	169.935 020	60	1 377.900
	Lu	169.938 830	70	1 373.570
171	Er	170.938 130	70	1 384.640
	Tm	170.936 530	70	1 385.350
	Yb	170.936 430	70	1 384.660
	Lu	170.938 140	1080	1 382.280
172	Er	171.939 330	80	1 391.590
	Tm	171.938 380	80	1 391.700
	Yb	171.936 360	70	1 392.800
	Lu	171.939 260	1080	1 389.320
173	Tm	172.939 480	80	1 398.740
	Yb	172.938 060	70	1 399.280
	Lu	172.938 800	80	1 397.810
174	Tm	173.941 970	120	1 404.500
	Yb	173.938 740	60	1 406.720
	Lu	173.940 350	70	1 404.440
	Hf	173.940 360	70	1 403.640
175	Tm	174.943 830	1080	1 410.840
	Yb	174.941 140	60	1 412.550
	Lu	174.940 640	60	1 412.240
	Hf	174.941 610	1080	1 410.560
176	Tm	175.947 190	130	1 415.770
	Yb	175.942 680	70	1 419.190
	Lu	175.942 660	60	1 418.430
	Hf	175.941 570	60	1 418.660
177	Yb	176.945 410	90	1 424.720
	Lu	176.943 930	80	1 425.320
	Hf	176.943 400	80	1 425.030
	Ta	176.944 650	80	1 423.080
178	Yb	177.947 370	1080	1 430.970
	Lu	177.946 300	90	1 431.180
	Hf	177.943 880	80	1 432.650
	Ta	177.945 930	130	1 429.960
179	Lu	178.947 470	100	1 438.160
	Hf	178.946 030	90	1 438.720
	Ta	178.946 160	90	1 437.820
180	Lu	179.950 370	150	1 443.540
	Hf	179.946 820	100	1 446.050
	Ta	179.947 544	48	1 444.602
	W	179.947 000	50	1 444.320
181	Hf	180.949 105	42	1 452.001
	Ta	180.948 007	42	1 452.242
	W	180.948 211	47	1 451.269
182	Hf	181.950 700	220	1 458.580
	Ta	181.950 167	42	1 458.301
	W	181.948 301	41	1 459.257
	Re	181.951 372	47	1 455.614
183	Hf	182.953 830	220	1 463.740
	Ta	182.951 470	43	1 465.159
	W	182.950 324	41	1 465.444
	Re	182.951 260	1070	1 463.790
184	Ta	183.953 980	50	1 470.900
	W	183.951 025	43	1 472.863
	Re	183.952 780	1080	1 470.450
	Os	183.952 750	70	1 469.690
185	Ta	184.955 560	70	1 477.490
	W	184.953 519	43	1 478.611
	Re	184.953 059	43	1 478.257
	Os	184.954 113	43	1 476.493
186	Ta	185.958 410	330	1 482.910
	W	185.954 440	45	1 485.824
	Re	185.955 020	70	1 484.500
	Os	185.953 870	70	1 484.790
	Ir	185.957 990	80	1 480.170
187	W	186.957 244	45	1 491.284
	Re	186.955 833	44	1 491.815
	Os	186.955 832	44	1 491.034
	Ir	186.957 560	1070	1 488.640
188	W	187.958 816	48	1 497.891
	Re	187.958 353	47	1 497.540
	Os	187.956 081	47	1 498.873
	Ir	187.959 122	49	1 495.259
	Pt	187.959 670	70	1 493.970

A	El.	Atomic Mass (u)	Mass Error*	Binding Energy† (MeV)
189	Re	188.959 370	90	1 504.660
	Os	188.958 300	90	1 504.880
	Ir	188.958 910	1080	1 503.530
	Pt	188.960 610	1520	1 501.160
190	Re	189.961 960	440	1 510.330
	Os	189.958 630	80	1 512.640
	Ir	189.960 830	180	1 509.810
	Pt	189.959 950	70	1 509.840
	Au	189.964 710	1080	1 504.630
191	Os	190.960 970	60	1 518.530
	Ir	190.960 640	60	1 518.060
	Pt	190.961 450	1080	1 516.520
	Au	190.963 550	1520	1 513.790
192	Os	191.961 450	60	1 526.160
	Ir	191.962 700	60	1 524.210
	Pt	191.961 150	60	1 524.880
	Au	191.964 620	80	1 520.860
	Hg	191.966 160	1080	1 518.640
193	Os	192.964 227	35	1 531.643
	Ir	192.963 012	35	1 531.993
	Pt	192.963 060	31	1 531.165
	Au	192.964 240	1070	1 529.280
	Hg	192.966 750	1070	1 526.160
194	Os	193.965 229	25	1 538.781
	Ir	193.965 125	25	1 538.096
	Pt	193.962 725	23	1 539.549
	Au	193.965 418	28	1 536.258
	Hg	193.965 790	1070	1 535.130
	Tl	193.971 570	1520	1 528.960
195	Os	194.968 000	500	1 544.200
	Ir	194.965 890	110	1 545.460
	Pt	194.964 813	18	1 545.675
	Au	194.965 051	19	1 544.672
	Hg	194.966 620	1070	1 542.430
	Tl	194.969 840	1090	1 538.650
196	Ir	195.968 250	1070	1 551.330
	Pt	195.964 967	15	1 553.604
	Au	195.966 555	14	1 551.342
	Hg	195.965 820	14	1 551.244
	Tl	195.970 760	160	1 545.860
	Pb	195.973 800	1090	1 542.250
197	Ir	196.969 490	220	1 558.240
	Pt	196.967 347	13	1 559.458
	Au	196.966 541	10	1 559.426
	Hg	196.967 360	44	1 557.881
	Tl	196.969 720	170	1 554.900
	Pb	196.974 090	1090	1 550.050
198	Ir	197.972 620	320	1 563.400
	Pt	197.967 895	23	1 567.019
	Au	197.968 231	7	1 565.923
	Hg	197.966 756	7	1 566.515
	Tl	197.970 470	90	1 562.270
	Pb	197.972 410	1080	1 559.680
	Bi	197.980 370	1520	1 551.490
199	Pt	198.970 580	29	1 572.589
	Au	198.968 773	13	1 573.490
	Hg	198.968 279	7	1 573.168
	Tl	198.969 460	320	1 571.290
	Pb	198.972 860	1120	1 567.330
	Bi	198.978 440	1090	1 561.350
200	Pt	199.971 430	1080	1 579.870
	Au	199.970 700	100	1 579.770
	Hg	199.968 327	6	1 581.194
	Tl	199.970 962	8	1 577.958
	Pb	199.971 970	1070	1 576.240
	Bi	199.978 940	1520	1 568.960
	Po	199.982 820	1090	1 564.570
201	Pt	200.974 770	120	1 584.830
	Au	200.971 920	110	1 586.700
	Hg	200.970 308	7	1 587.421
	Tl	200.970 750	60	1 586.230
	Pb	200.972 860	1080	1 583.480
	Bi	200.977 370	1520	1 578.490
	Po	200.983 020	1090	1 572.450
202	Au	201.974 120	1070	1 592.720
	Hg	201.970 642	7	1 595.181
	Tl	201.971 950	25	1 593.180
	Pb	201.972 003	40	1 592.348
	Bi	201.977 880	1070	1 586.100
	Po	201.981 130	1080	1 582.280
	At	201.989 800	1520	1 573.420
203	Au	202.975 130	1070	1 599.850
	Hg	202.972 880	8	1 601.168
	Tl	202.972 353	8	1 600.876
	Pb	202.973 229	13	1 599.278
	Bi	202.976 650	60	1 595.310
	Po	202.981 470	1120	1 590.040
	At	202.987 710	1090	1 583.440
204	Hg	203.973 495	7	1 608.666
	Tl	203.973 865	8	1 607.539
	Pb	203.973 044	8	1 607.522
	Bi	203.977 810	1070	1 602.300
	Po	203.980 460	1070	1 599.050
	At	203.988 060	1520	1 591.190
	Rn	203.992 300	1090	1 586.450

A	El.	Atomic Mass (u)	Mass Error*	Binding Energy† (MeV)
205	Hg	204.976 210	110	1 614.210
	Tl	204.974 442	8	1 615.073
	Pb	204.974 480	9	1 614.256
	Bi	204.977 382	13	1 610.769
	Po	204.981 200	1080	1 606.430
	At	204.986 440	1520	1 600.770
	Rn	204.992 560	1530	1 594.290
206	Hg	205.977 513	23	1 621.067
	Tl	205.976 104	8	1 621.597
	Pb	205.974 468	7	1 622.338
	Bi	205.978 389	28	1 617.904
	Po	205.980 324	41	1 615.318
	At	205.986 790	1070	1 608.510
	Rn	205.990 580	1080	1 604.200
	Fr	205.999 840	1520	1 594.790
207	Tl	206.977 450	11	1 628.414
	Pb	206.975 903	7	1 629.073
	Bi	206.978 438	8	1 625.929
	Po	206.981 558	11	1 622.240
	At	206.985 560	60	1 617.730
	Rn	206.990 760	1120	1 612.100
	Fr	206.997 730	1090	1 604.830
208	Tl	207.982 013	9	1 632.235
	Pb	207.976 650	7	1 636.448
	Bi	207.979 731	9	1 632.796
	Po	207.981 243	12	1 630.605
	At	207.986 610	1080	1 624.830
	Rn	207.989 790	1070	1 621.080
	Fr	207.997 950	1520	1 612.700
209	Tl	208.985 296	37	1 637.249
	Pb	208.981 082	11	1 640.391
	Bi	208.980 394	8	1 640.250
	Po	208.982 426	13	1 637.575
	At	208.986 167	13	1 633.307
	Rn	208.990 420	1080	1 628.570
	Fr	208.996 320	1520	1 622.280
210	Tl	209.990 054	29	1 640.888
	Pb	209.984 187	7	1 645.571
	Bi	209.984 121	7	1 644.849
	Po	209.982 876	7	1 645.227
	At	209.987 036	28	1 640.569
	Rn	209.989 540	42	1 637.454
	Fr	209.996 570	1070	1 630.120
211	Pb	210.988 742	22	1 649.399
	Bi	210.987 300	11	1 649.960
	Po	210.986 657	8	1 649.777
	At	210.987 462	8	1 648.244
	Rn	210.990 566	11	1 644.570
	Fr	210.995 330	60	1 639.350
	Ra	211.000 950	1550	1 633.330
212	Pb	211.991 892	9	1 654.537
	Bi	211.991 276	8	1 654.328
	Po	211.988 865	6	1 655.792
	At	211.990 723	23	1 653.278
	Rn	211.990 707	13	1 652.511
	Fr	211.996 230	1080	1 646.580
	Ra	211.999 950	1070	1 642.330
213	Pb	212.996 580	1070	1 658.240
	Bi	212.994 377	14	1 659.511
	Po	212.992 849	10	1 660.152
	At	212.993 070	210	1 659.170
	Rn	212.993 935	24	1 657.576
	Fr	212.996 184	17	1 654.698
	Ra	213.000 420	1080	1 649.970
	Ac	213.007 050	1520	1 643.010
214	Pb	213.999 844	12	1 663.272
	Bi	213.998 726	15	1 663.532
	Po	213.995 204	6	1 666.029
	At	213.996 332	12	1 664.196
	Rn	213.995 380	1070	1 664.300
	Fr	213.998 980	40	1 660.160
	Ra	213.999 990	50	1 658.440
	Ac	214.007 100	1080	1 651.040
215	Bi	215.001 850	100	1 668.690
	Po	214.999 449	11	1 670.147
	At	214.998 656	14	1 670.103
	Rn	214.998 690	110	1 669.290
	Fr	215.000 400	30	1 666.910
	Ra	215.002 765	26	1 663.930
216	Bi	216.006 310	1070	1 672.610
	Po	216.001 908	9	1 675.928
	At	216.002 416	11	1 674.672
	Rn	216.000 272	12	1 675.887
	Fr	216.003 100	1070	1 672.470
	Ra	216.003 490	30	1 671.330
217	Po	217.006 340	1070	1 679.870
	At	217.004 708	14	1 680.609
	Rn	217.003 920	11	1 680.560
	Fr	217.004 750	300	1 679.000
	Ra	217.006 390	40	1 676.700
218	Po	218.009 009	12	1 685.456
	At	218.008 710	15	1 684.953
	Rn	218.005 606	12	1 687.062
	Fr	218.007 521	16	1 684.496
	Ra	218.007 170	1520	1 684.040
219	At	219.011 320	90	1 690.600
	Rn	219.009 508	11	1 691.499
	Fr	219.009 250	26	1 690.956
	Ra	219.010 050	150	1 689.430

A	El.	Atomic Mass (u)	Mass Error*	Binding Energy† (MeV)
220	At	220.015 140	1070	1 695.100
	Rn	220.011 387	9	1 697.819
	Fr	220.012 318	13	1 696.170
	Ra	220.011 026	16	1 696.591
221	Rn	221.015 390	1520	1 702.170
	Fr	221.014 244	15	1 702.447
	Ra	221.013 913	12	1 701.973
	Ac	221.015 680	370	1 699.550
222	Rn	222.017 610	12	1 708.166
	Fr	222.017 550	30	1 707.440
	Ra	222.015 375	16	1 708.683
	Ac	222.017 779	20	1 705.661
223	Fr	223.019 760	11	1 713.452
	Ra	223.018 527	11	1 713.818
	Ac	223.019 133	26	1 712.470
	Th	223.020 920	190	1 710.030
224	Fr	224.023 320	1070	1 718.210
	Ra	224.020 203	9	1 720.328
	Ac	224.021 701	15	1 718.150
	Th	224.021 470	20	1 717.583
225	Ra	225.023 630	13	1 725 208
	Ac	225.023 214	15	1 724.813
	Th	225.023 945	14	1 723.349
	Pa	225.026 230	1140	1 720.430
226	Ra	226.025 438	12	1 731.594
	Ac	226.026 101	21	1 730.195
	Th	226.024 900	20	1 730.531
	Pa	226.027 882	22	1 726.971
227	Ra	227.029 180	24	1 736.181
	Ac	227.027 774	11	1 736.708
	Th	227.027 727	11	1 735.969
	Pa	227.028 801	27	1 734.190
	U	227.031 200	1090	1 731.170
228	Ra	228.031 096	13	1 742.468
	Ac	228.031 037	13	1 741.740
	Th	228.028 733	9	1 743.103
	Pa	228.030 990	16	1 740.219
	U	228.031 377	22	1 739.076
229	Ra	229.034 870	1520	1 747.020
	Ac	229.032 940	1070	1 748.040
	Th	229.031 781	12	1 748.336
	Pa	229.032 081	16	1 747.274
	U	229.033 496	14	1 745.173
230	Ra	230.037 130	1520	1 752.990
	Ac	230.036 270	1070	1 753.010
	Th	230.033 159	12	1 755.124
230	Pa	230.034 541	21	1 753.054
	U	230.033 935	20	1 752.836
	Np	230.037 750	1070	1 748.500
231	Ac	231.038 570	110	1 758.930
	Th	231.036 318	11	1 760.252
	Pa	231.035 903	11	1 759.857
	U	231.036 290	50	1 758.720
	Np	231.038 270	60	1 756.080
232	Th	232.038 079	12	1 766.683
	Pa	232.038 592	24	1 765.423
	U	232.037 148	10	1 765.986
	Np	232.039 950	1070	1 762.600
	Pu	232.041 170	60	1 760.670
233	Th	233.041 604	12	1 771.472
	Pa	233.040 268	12	1 771.934
	U	233.039 654	12	1 771.723
	Np	233.040 830	1070	1 769.850
	Pu	233.042 987	26	1 767.050
234	Th	234.043 636	13	1 777.651
	Pa	234.043 354	13	1 777.131
	U	234.040 976	12	1 778.564
	Np	234.042 908	20	1 775.981
	Pu	234.043 313	20	1 774.822
235	Pa	235.045 450	110	1 783.250
	U	235.043 943	11	1 783.871
	NP	235.044 075	11	1 782.965
	Pu	235.045 290	60	1 781.050
236	Pa	236.048 700	1070	1 788.290
	U	236.045 591	12	1 790.407
	NP	236.046 605	15	1 788.680
	Pu	236.046 049	11	1 788.416
	Am	236.049 310	1520	1 784.590
237	Pa	237.051 220	60	1 794.020
	U	237.048 750	12	1 795.536
	NP	237.048 195	12	1 795.271
	Pu	237.048 434	13	1 794.266
	Am	237.050 060	1520	1 791.970
238	U	238.050 819	12	1 801.680
	NP	238.050 970	14	1 800.757
	Pu	238.049 582	12	1 801.268
	Am	238.052 010	1070	1 798.230
	Cm	238.053 030	40	1 796.490
239	U	239.054 328	13	1 806.484
	Np	239.052 951	12	1 806.984
	Pu	239.052 175	12	1 806.924
	Am	239.053 042	24	1 805.330
	Cm	239.054 900	1070	1 802.820

A	El.	Atomic Mass (u)	Mass Error*	Binding Energy† (MeV)
240	U	240.056 633	17	1 812.408
	Np	240.056 080	70	1 812.140
	Pu	240.053 836	12	1 813.448
	Am	240.055 340	1070	1 811.270
	Cm	240.055 518	11	1 810.316
241	Np	241.058 330	110	1 818 110
	Pu	241.056 873	12	1 818 691
	Am	241.056 850	12	1 817.929
	Cm	241.057 679	13	1 816.375
	Bk	241.060 240	1070	1 813.200
242	Np	242.061 780	1070	1 822.980
	Pu	242.058 769	12	1 824.996
	Am	242.059 573	14	1 823.465
	Cm	242.058 860	12	1 823.347
	Bk	242.062 080	1070	1 819.560
	Cf	242.063 670	40	1 817.300
243	Pu	243.062 031	15	1 830.029
	Am	243.061 393	12	1 829.840
	Cm	243.061 400	12	1 829.052
	Bk	243.063 022	25	1 826.760
	Cf	243.065 330	1520	1 823.830
244	Pu	244.064 235	17	1 836.047
	Am	244.064 310	12	1 835.196
	Cm	244.062 775	12	1 835.842
	Bk	244.065 220	1070	1 832.780
	Cf	244.065 988	11	1 831.284
245	Pu	245.067 800	1070	1 840.800
	Am	245.066 477	13	1 841.249
	Cm	245.065 511	12	1 841.366
	Bk	245.066 393	13	1 839.762
	Cf	245.068 071	13	1 837.416
	Es	245.071 330	1520	1 833.600
246	Pu	246.070 120	60	1 846.710
	Am	246.069 720	60	1 846.300
	Cm	246.067 250	13	1 847.817
	Bk	246.068 820	1070	1 845.570
	Cf	246.068 837	16	1 844.774
	Es	246.072 970	1520	1 840.140
	Fm	246.075 260	50	1 837.230
247	Am	247.072 100	1070	1 852.160
	Cm	247.070 380	15	1 852.973
	Bk	247.070 290	30	1 852.280
	Cf	247.071 180	760	1 850.660
	Es	247.073 620	40	1 847.600
	Fm	247.076 740	1860	1 843.920
248	Am	248.075 710	1070	1 856.860
	Cm	248.072 379	16	1 859.182
	Bk	248.073 020	1070	1 857.800
	Cf	248.072 220	30	1 857.770
248	Es	248.075 500	1520	1 853.930
	Fm	248.077 190	30	1 851.570
249	Cm	249.075 985	17	1 863.895
	Bk	249.075 005	12	1 864.026
	Cf	249.074 870	12	1 863.369
	Es	249.076 380	30	1 861.180
	Fm	249.078 960	1070	1 857.990
250	Cm	250.078 420	1070	1 869.700
	Bk	250.078 337	16	1 868.993
	Cf	250.076 432	14	1 869.985
	Es	250.078 650	1070	1 867.130
	Fm	250.079 550	40	1 865.520
	Md	250.084 430	1860	1 860.190
251	Bk	251.080 810	1520	1 874.760
	Cf	251.079 591	18	1 875.114
	Es	251.079 970	50	1 873.980
	Fm	251.081 620	1320	1 871.660
	Md	251.084 870	1070	1 867.850
	No	251.088 860	2150	1 863.350
252	Bk	252.084 340	1070	1 879.540
	Cf	252.081 657	17	1 881.261
	Es	252.082 870	1070	1 879.350
	Fm	252.082 500	40	1 878.910
	Md	252.086 530	1860	1 874.380
	No	252.088 970	40	1 871.320
253	Cf	253.085 140	60	1 886.090
	Es	253.084 850	14	1 885.576
	Fm	253.085 200	1070	1 884.470
	Md	253.087 250	1070	1 881.780
	No	253.090 580	1520	1 877.890
254	Cf	254.087 390	1070	1 892.060
	Es	254.088 053	17	1 890.663
	Fm	254.086 883	15	1 890.972
	Md	254.089 630	1520	1 887.630
	No	254.090 990	40	1 885.580
255	Es	255.090 290	1520	1 896.650
	Fm	255.089 970	19	1 896.168
	Md	255.091 100	1070	1 894.330
	No	255.093 270	1700	1 891.520
256	Es	256.093 710	1520	1 901.540
	Fm	256.091 730	40	1 902.600
	Md	256.093 790	1520	1 899.900
	No	256.094 280	40	1 898.650
	Lw	256.098 570	1070	1 893.880
257	Fm	257.095 110	60	1 907.520
	Md	257.095 610	1070	1 906.270
	No	257.096 930	1520	1 904.260
	Lw	257.099 510	1520	1 901.070

DENSITY OF ELEMENTS AND COMMON MATERIALS

Element	At. No.	At. Wt.	MIP*	Density	Element	At. No.	At. Wt.	MIP*	Density
H	1	1.00797	18.0	0.0586	I	53	126.9044		4.93
He	2	4.0026	40.0	0.126	Xe	54	131.30	757.52	3.52
Li	3	6.939	39.032	0.534	Cs	55	132.905		1.873
Be	4	9.0122	56.0	1.8	Ba	56	137.34		3.5
B	5	10.811		2.34	La	57	138.91		6.155
C	6	12.01115	79.0	2.25	Ce	58	140.12		3.92
N	7	14.0067	92.0	0.808	Pr	59	140.907		6.5
O	8	15.9994	105.0	1.14	Nd	60	144.24		6.95
F	9	18.9984		1.11	Pm	61	147		
Ne	10	20.183	130.016	1.2	Sm	62	150.35		7.8
Na	11	22.9898		0.971	Eu	63	151.96		5.24
Mg	12	24.312	156.4	1.74	Gd	64	157.25		
Al	13	26.9815	163	2.699	Tb	65	158.924		
Si	14	28.086		2.42	Dy	66	162.50		8.56
P	15	30.9738		1.82	Ho	67	164.930		
S	16	32.064		2.07	Er	68	167.26		4.77
Cl	17	35.453		1.56	Tm	69	168.934		
Ar	18	39.948	240.0	1.40	Yb	70	173.04		
K	19	39.102		0.87	Lu	71	174.97		
Ca	20	40.08	200	1.55	Hf	72	178.49		13.3
Sc	21	44.956		3.02	Ta	73	180.948	720	16.6
Ti	22	47.90	225	4.5	W	74	183.85	740	19.3
V	23	50.942	254	5.96	Re	75	186.2		20.53
Cr	24	51.996		7.1	Os	76	190.2		22.48
Mn	25	54.9380		7.20	Ir	77	192.2	760	22.42
Fe	26	55.847	273	7.86	Pt	78	195.09	777	21.37
Co	27	58.9332	298	8.9	Au	79	196.967	786	19.32
Ni	28	58.71	312	8.90	Hg	80	200.59		13.546
Cu	29	63.54	322	8.94	Tl	81	204.37		11.85
Zn	30	65.37	331	7.14	Pb	82	207.19	818	11.35
Ga	31	69.72		5.91	Bi	83	208.980	826	9.747
Ge	32	72.59		5.36	Po	84	210		
As	33	74.9216		5.73	At	85	210		
Se	34	78.96		4.8	Rn	86	222		9.73
Br	35	79.909		3.12	Fr	87	223		
Kr	36	83.80	493.68	2.6	Ra	88	226		
Rb	37	85.47		1.53	Ac	89	227		
Sr	38	87.62		2.54	Th	90	232.038		11.3
Y	39	88.905		5.51	Pa	91	231		
Zr	40	91.22		6.4	U	92	238.03	908	18.68
Nb	41	92.906	410	8.4	Np	93			
Mo	42	95.94	420	10.2	Pu	94			
Tc	43	99			Am	95			
Ru	44	101.07		12.2	Cm	96			
Rh	45	102.905	450	12.5	Bk	97			
Pd	46	106.4	460	12.16	Cf	98			
Ag	47	107.870	485	10.50	Es	99			
Cd	48	112.40	468.0	8.65	Fm	100			
In	49	114.82	490	7.28	Md	101			
Sn	50	118.69	500	7.31	No	102			
Sb	51	121.75		6.691	Lw	103			
Te	52	127.60		6.24	Ku	104			

*Mean ionization potential.

Material	Density (gm/cm^3)
Air	0.001293
Asbestos	2.0 - 2.8
Asphalt	1.1 - 1.5
Bone	1.7 - 2.0
Brick	1.4 - 2.5
Cement	2.7 - 3.0
Clay	1.8 - 2.6
Concrete, siliceous	2.25 - 2.40
Ebonite	1.15
Gelatin	1.27
Glass (common)	2.4 - 2.8
Glass (flint)	2.9 - 5.9
Granite	2.60 - 2.76
Graphite	2.30 - 2.72
Gypsum	2.31 - 2.33
Limestone	1.87 - 2.76
Linoleum	1.18
Marble	2.47 - 2.86
Paraffin	0.87 - 0.91
Plaster, sand	1.54
Pressed wood:	
Pulp Board	0.19
Sandstone	1.90
Slate	2.6 - 3.3
Tile	1.6 - 2.5
Water	1.000
Water (heavy)	1.105
Wood:	
Oak	0.60 - 0.90
White Pine	0.35 - 0.50
Yellow Pine	0.37 - 0.60

Source: "Medical X-Ray Protection up to Three Million Volts," National Bureau of Standards Handbook No. 76, 1961;
"Handbook of Chemistry and Physics," Chemical Rubber Co., 48th ed., 1967-1968; and
Trout, E. Dale, *et al.*, "Conventional Building Materials as Protective Barriers," *Radiology*, Vol. 76, No. 2 (Feb. 1961), pp. 237-244.

PERIODIC TABLE OF THE ELEMENTS

According to latest reports including Commission on Atomic Weights, International Union of Pure and Applied Chemistry

BASED ON CARBON-12

IMPORTANT ATOMIC CONSTANTS

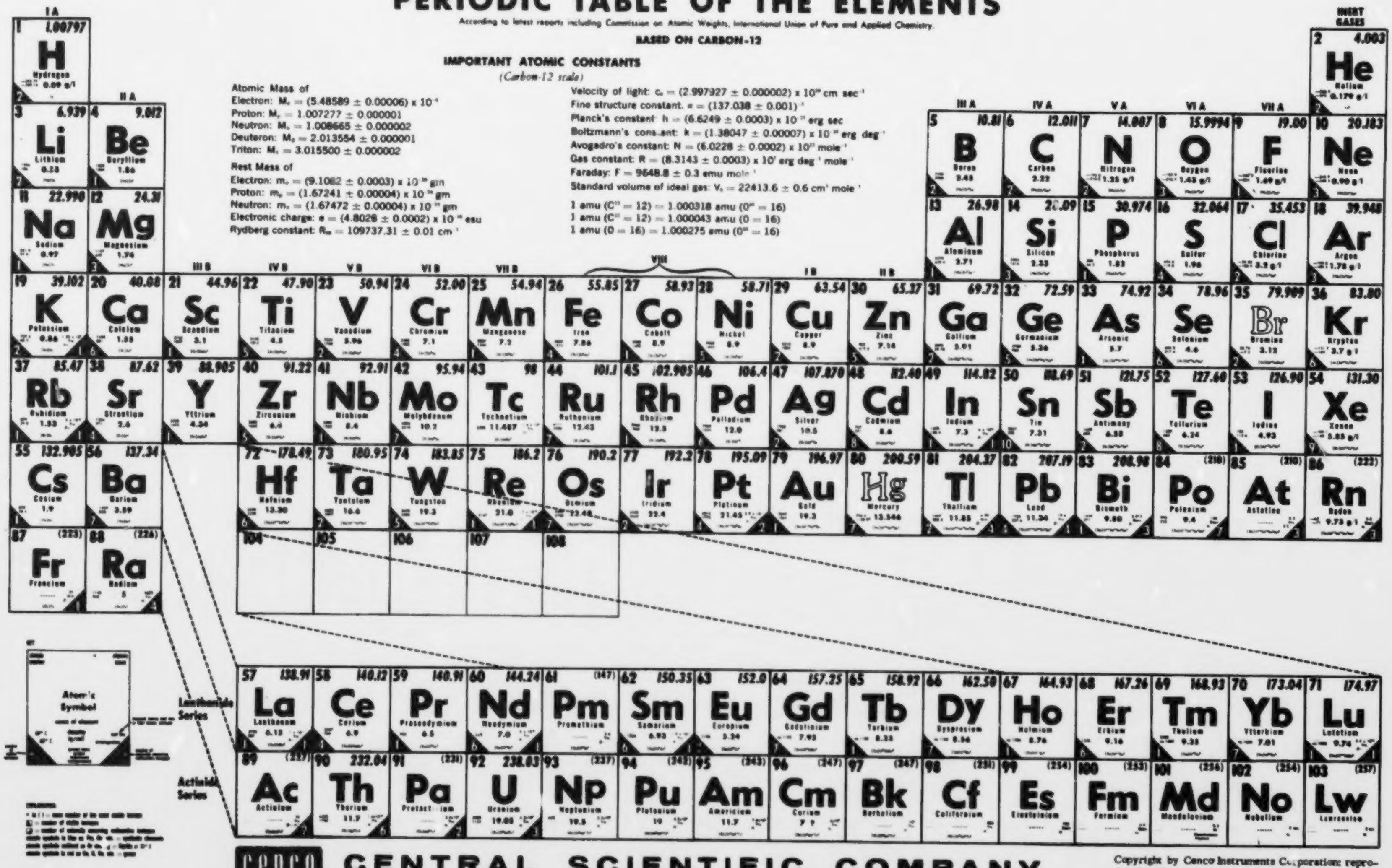
(Carbon-12 scale)

Atomic Mass of
Electron: $M_e = (5.48589 \pm 0.00006) \times 10^{-4}$
Proton: $M_p = 1.007277 \pm 0.000001$
Neutron: $M_n = 1.008665 \pm 0.000002$
Deuteron: $M_d = 2.013554 \pm 0.000001$
Triton: $M_t = 3.015500 \pm 0.000002$

Rest Mass of
Electron: $m_e = (9.1082 \pm 0.0003) \times 10^{-28}$ gm
Proton: $m_p = (1.67241 \pm 0.00004) \times 10^{-24}$ gm
Neutron: $m_n = (1.67472 \pm 0.00004) \times 10^{-24}$ gm
Electronic charge: $e = (4.8028 \pm 0.0002) \times 10^{-10}$ esu
Rydberg constant: $R_\infty = 109737.31 \pm 0.01\ \text{cm}^{-1}$

Velocity of light: $c_o = (2.997927 \pm 0.000002) \times 10^{10}\ \text{cm sec}^{-1}$
Fine structure constant. $\alpha = (137.038 \pm 0.001)^{-1}$
Planck's constant $h = (6.6249 \pm 0.0003) \times 10^{-27}$ erg sec
Boltzmann's constant: $k = (1.38047 \pm 0.00007) \times 10^{-16}\ \text{erg deg}^{-1}$
Avogadro's constant: $N = (6.0228 \pm 0.0002) \times 10^{23}\ \text{mole}^{-1}$
Gas constant: $R = (8.3143 \pm 0.0003) \times 10^{7}\ \text{erg deg}^{-1}\ \text{mole}^{-1}$
Faraday: $F = 9648.8 \pm 0.3\ \text{emu mole}^{-1}$
Standard volume of ideal gas: $V_o = 22413.6 \pm 0.6\ \text{cm}^3\ \text{mole}^{-1}$

1 amu ($C^{12} = 12$) = 1.000318 amu ($O^{16} = 16$)
1 amu ($C^{12} = 12$) = 1.000043 amu ($O = 16$)
1 amu ($O = 16$) = 1.000275 amu ($O^{16} = 16$)


I A
II A
III B
IV B
V B
VI B
VII B
VIII
I B
II B
III A
IV A
V A
VI A
VII A
INERT GASES
1 H 1.00797 Hydrogen
2 He 4.003 Helium
3 Li 6.939 Lithium
4 Be 9.012 Beryllium
5 B 10.81 Boron
6 C 12.011 Carbon
7 N 14.007 Nitrogen
8 O 15.9994 Oxygen
9 F 19.00 Fluorine
10 Ne 20.183 Neon
11 Na 22.990 Sodium
12 Mg 24.31 Magnesium
13 Al 26.98 Aluminum
14 Si 28.09 Silicon
15 P 30.974 Phosphorus
16 S 32.064 Sulfur
17 Cl 35.453 Chlorine
18 Ar 39.948 Argon
19 K 39.102 Potassium
20 Ca 40.08 Calcium
21 Sc 44.96 Scandium
22 Ti 47.90 Titanium
23 V 50.94 Vanadium
24 Cr 52.00 Chromium
25 Mn 54.94 Manganese
26 Fe 55.85 Iron
27 Co 58.93 Cobalt
28 Ni 58.71 Nickel
29 Cu 63.54 Copper
30 Zn 65.37 Zinc
31 Ga 69.72 Gallium
32 Ge 72.59 Germanium
33 As 74.92 Arsenic
34 Se 78.96 Selenium
35 Br 79.909 Bromine
36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium
38 Sr 87.62 Strontium
39 Y 88.905 Yttrium
40 Zr 91.22 Zirconium
41 Nb 92.91 Niobium
42 Mo 95.94 Molybdenum
43 Tc 98 Technetium
44 Ru 101.1 Ruthenium
45 Rh 102.905 Rhodium
46 Pd 106.4 Palladium
47 Ag 107.870 Silver
48 Cd 112.40 Cadmium
49 In 114.82 Indium
50 Sn 118.69 Tin
51 Sb 121.75 Antimony
52 Te 127.60 Tellurium
53 I 126.90 Iodine
54 Xe 131.30 Xenon
55 Cs 132.905 Cesium
56 Ba 137.34 Barium
72 Hf 178.49 Hafnium
73 Ta 180.95 Tantalum
74 W 183.85 Tungsten
75 Re 186.2 Rhenium
76 Os 190.2 Osmium
77 Ir 192.2 Iridium
78 Pt 195.09 Platinum
79 Au 196.97 Gold
80 Hg 200.59 Mercury
81 Tl 204.37 Thallium
82 Pb 207.19 Lead
83 Bi 208.98 Bismuth
84 Po (210) Polonium
85 At (210) Astatine
86 Rn (222) Radon
87 Fr (223) Francium
88 Ra (226) Radium
104
105
106
107
108
Lanthanide Series
57 La 138.91 Lanthanum
58 Ce 140.12 Cerium
59 Pr 140.91 Praseodymium
60 Nd 144.24 Neodymium
61 Pm (147) Promethium
62 Sm 150.35 Samarium
63 Eu 152.0 Europium
64 Gd 157.25 Gadolinium
65 Tb 158.92 Terbium
66 Dy 162.50 Dysprosium
67 Ho 164.93 Holmium
68 Er 167.26 Erbium
69 Tm 168.93 Thulium
70 Yb 173.04 Ytterbium
71 Lu 174.97 Lutetium
Actinide Series
89 Ac (227) Actinium
90 Th 232.04 Thorium
91 Pa (231) Protactinium
92 U 238.03 Uranium
93 Np (237) Neptunium
94 Pu (242) Plutonium
95 Am (243) Americium
96 Cm (247) Curium
97 Bk (247) Berkelium
98 Cf (251) Californium
99 Es (254) Einsteinium
100 Fm (253) Fermium
101 Md (256) Mendelevium
102 No (254) Nobelium
103 Lw (257) Lawrencium
Atom's Symbol

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LIST OF ELEMENTS

Atomic Number	Symbol	Name	Atomic Number	Symbol	Name
0	n	neutron	52	Te	tellurium
1	H	hydrogen	53	I	iodine
2	He	helium	54	Xe	xenon
3	Li	lithium	55	Cs	cesium
4	Be	beryllium	56	Ba	barium
5	B	boron	57	La	lanthanum
6	C	carbon	58	Ce	cerium
7	N	nitrogen	59	Pr	praseodymium
8	O	oxygen	60	Nd	neodymium
9	F	fluorine	61	Pm	promethium
10	Ne	neon	62	Sm	samarium
11	Na	sodium	63	Eu	europium
12	Mg	magnesium	64	Gd	gadolinium
13	Al	aluminum	65	Tb	terbium
14	Si	silicon	66	Dy	dysprosium
15	P	phosphorus	67	Ho	holmium
16	S	sulfur	68	Er	erbium
17	Cl	chlorine	69	Tm	thulium
18	Ar	argon	70	Yb	ytterbium
19	K	potassium	71	Lu	lutetium
20	Ca	calcium	72	Hf	hafnium
21	Sc	scandium	73	Ta	tantalum
22	Ti	titanium	74	W	tungsten
23	V	vanadium	75	Re	rhenium
24	Cr	chromium	76	Os	osmium
25	Mn	manganese	77	Ir	iridium
26	Fe	iron	78	Pt	platinum
27	Co	cobalt	79	Au	gold
28	Ni	nickel	80	Hg	mercury
29	Cu	copper	81	Tl	thallium
30	Zn	zinc	82	Pb	lead
31	Ga	gallium	83	Bi	bismuth
32	Ge	germanium	84	Po	polonium
33	As	arsenic	85	At	astatine
34	Se	selenium	86	Rn	radon
35	Br	bromine	87	Fr	francium
36	Kr	krypton	88	Ra	radium
37	Rb	rubidium	89	Ac	actinium
38	Sr	strontium	90	Th	thorium
39	Y	yttrium	91	Pa	protactinium
40	Zr	zirconium	92	U	uranium
41	Nb	niobium	93	Np	neptunium
42	Mo	molybdenum	94	Pu	plutonium
43	Tc	technetium	95	Am	americium
44	Ru	ruthenium	96	Cm	curium
45	Rh	rhodium	97	Bk	berkelium
46	Pd	palladium	98	Cf	californium
47	Ag	silver	99	Es	einsteinium
48	Cd	cadmium	100	Fm	fermium
49	In	indium	101	Md	mendelevium
50	Sn	tin	102	No	nobelium
51	Sb	antimony	103	Lw	lawrencium

CHART OF THE NUCLIDES

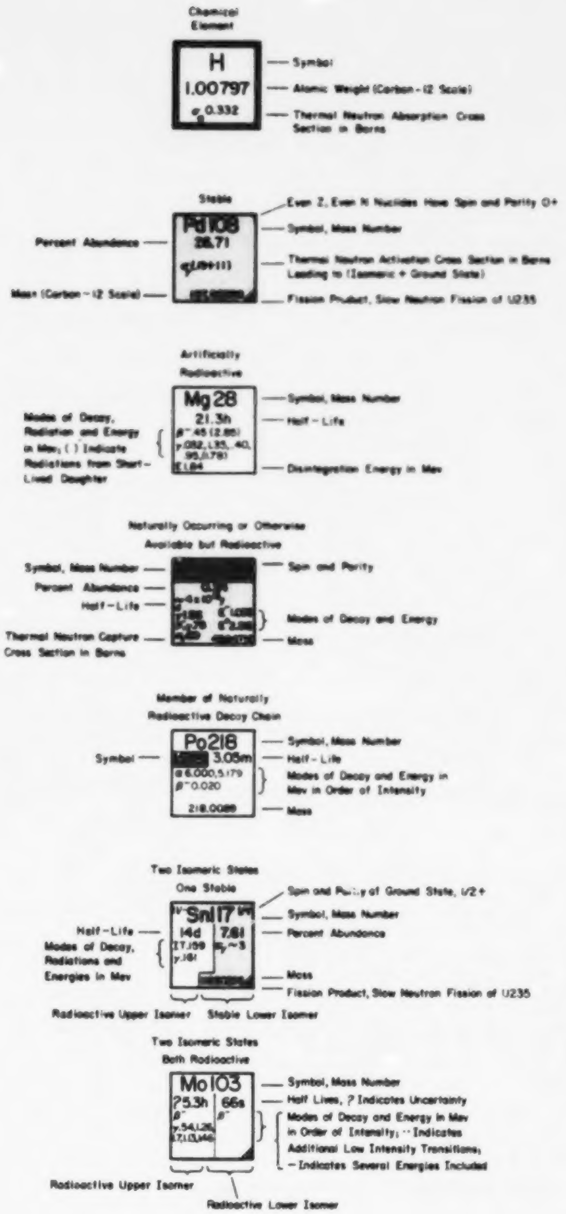
KNOLLS ATOMIC POWER LABORATORY

U.S. ATOMIC ENERGY COMMISSION

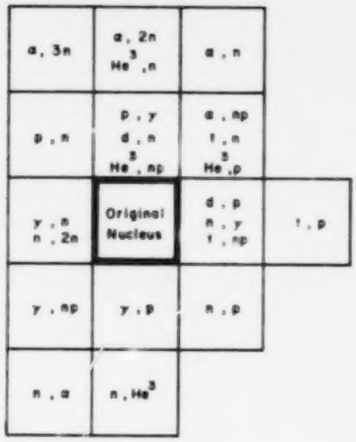
Operated by the General Electric Company

TENTH EDITION—REVISED TO DECEMBER 1968

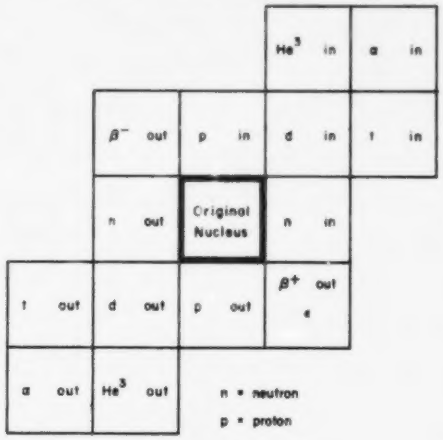
Prepared by: Norman E. Holden
F. William Walker


Chemical Element
H
1.00797
σa 0.332
Symbol
Atomic Weight (Carbon - 12 Scale)
Thermal Neutron Absorption Cross Section in Barns
Stable
Pd108
26.71
Percent Abundance
Mass (Carbon - 12 Scale)
Even Z, Even N Nuclides Have Spin and Parity 0+
Symbol, Mass Number
Thermal Neutron Activation Cross Section in Barns Leading to (Isomeric + Ground State)
Fission Product, Slow Neutron Fission of U235
Artificially Radioactive
Mg 28
21.3h
β⁻.45 (2.85)
γ.032, 1.35, .40, .95,(1.78)
E1.84
Modes of Decay, Radiation and Energy in Mev; ( ) Indicate Radiations from Short-Lived Daughter
Symbol, Mass Number
Half - Life
Disintegration Energy in Mev
Naturally Occurring or Otherwise Available but Radioactive
Symbol, Mass Number
Percent Abundance
Half-Life
Thermal Neutron Capture Cross Section in Barns
Spin and Parity
Modes of Decay and Energy
Mass
Member of Naturally Radioactive Decay Chain
Po218
3.05m
α 6.000, 5.179
β⁻ 0.020
218.0089
Symbol
Symbol, Mass Number
Half - Life
Modes of Decay and Energy in Mev in Order of Intensity
Mass
Two Isomeric States One Stable
Sn117
14d
IT.159
γ.161
7.61
Half-Life
Modes of Decay, Radiations and Energies in Mev
Spin and Parity of Ground State, 1/2+
Symbol, Mass Number
Percent Abundance
Mass
Fission Product, Slow Neutron Fission of U235
Radioactive Upper Isomer
Stable Lower Isomer
Two Isomeric States Both Radioactive
Mo103
?5.3h
66s
β⁻
Symbol, Mass Number
Half Lives, ? Indicates Uncertainty
Modes of Decay and Energy in Mev in Order of Intensity; ·· Indicates Additional Low Intensity Transitions; ~ Indicates Several Energies Included
Radioactive Upper Isomer
Radioactive Lower Isomer

Displacements Caused by Nuclear Bombardment Reactions


α, 3n
α, 2n
He³, n
α, n
p, n
p, γ
d, n
He³, np
α, np
t, n
He³, p
γ, n
n, 2n
Original Nucleus
d, p
n, γ
t, np
t, p
γ, np
γ, p
n, p
n, α
n, He³

Relative Locations of the Products of Various Nuclear Processes


He³ in
α in
β⁻ out
p in
d in
t in
n out
Original Nucleus
n in
t out
d out
p out
β⁺ out
ε
α out
He³ out

n = neutron
p = proton
d = deuteron
t = triton (H³)
α = alpha particle
β⁻ = negative electron
β⁺ = positron
ε = electron capture

SYMBOLS

TIME

ms	milliseconds $(10^{-3}s)$
μs	microseconds $(10^{-6}s)$
s	seconds
m	minutes
h	hours
d	days
y	years

RADIATIONS AND DECAY

α	alpha particle	ε	electron capture
β⁻	negative electron	IT	isomeric transition
β⁺	positron	D	radiation delayed
γ	gamma ray	SF	spontaneous fission
n	neutron	E	disintegration energy
p	proton	e⁻	conversion electron

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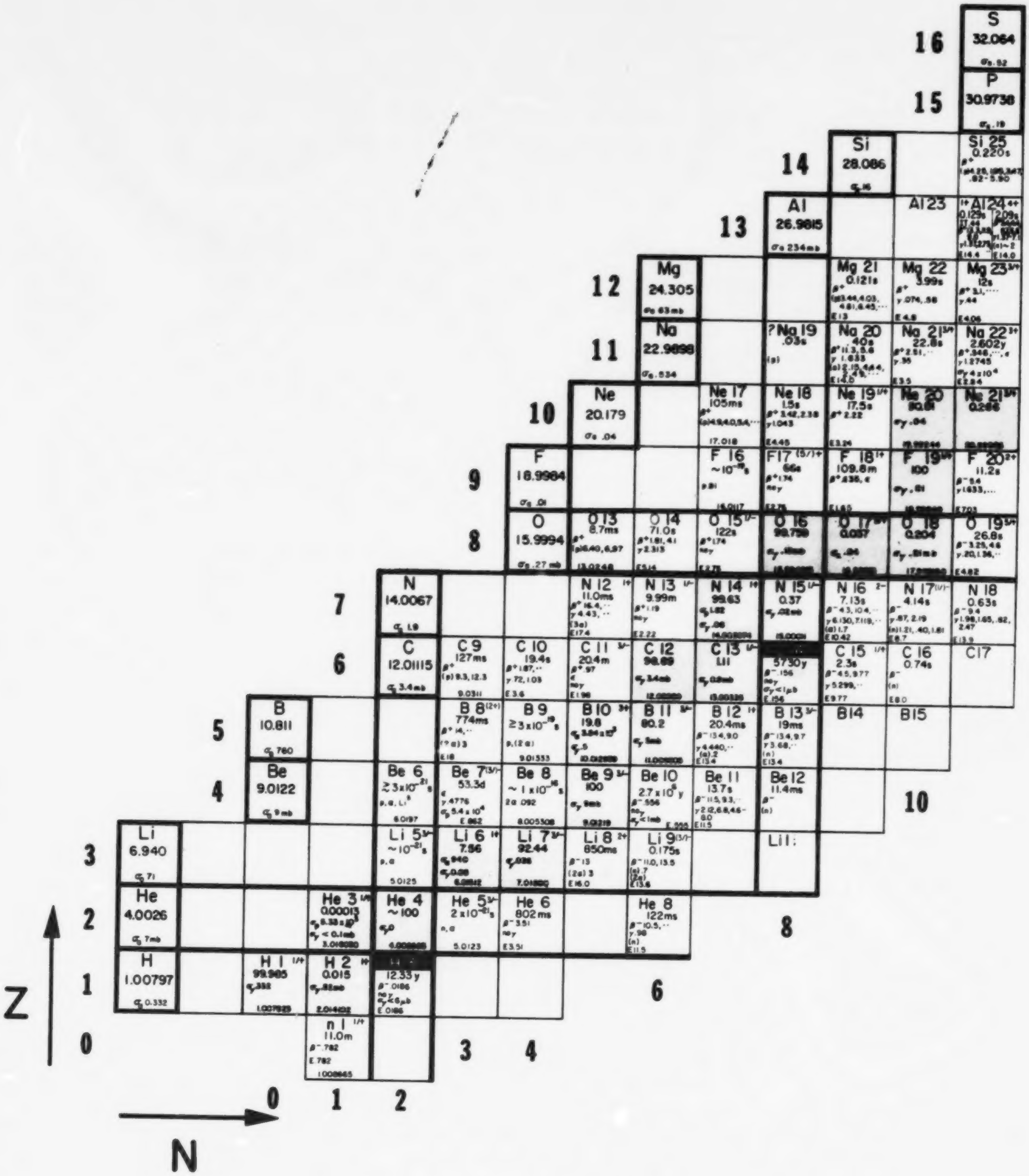
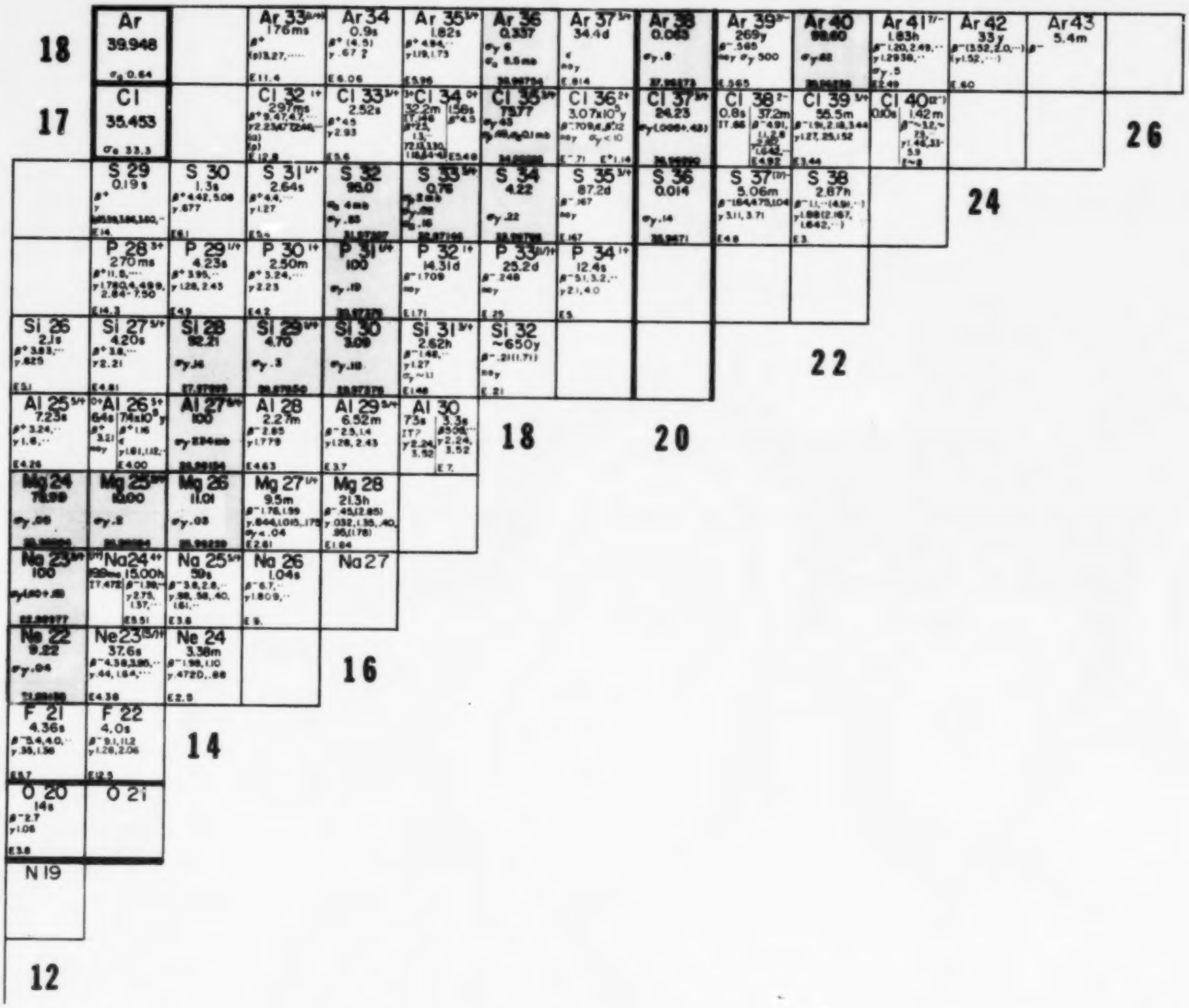

Z
N
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
S 32.064
P 30.9738
Si 28.086
Si 25 0.220s
Al 26.9815
Al 23
Al 24
Mg 24.305
Mg 21 0.121s
Mg 22 3.99s
Mg 23 12s
Na 22.9898
? Na 19 .03s
Na 20 .40s
Na 21 22.8s
Na 22 2.602y
Ne 20.179
Ne 17 105ms
Ne 18 1.5s
Ne 19 17.5s
Ne 20 90.51
Ne 21 0.266
F 18.9984
F 16 ~10⁻¹⁹s
F 17 66s
F 18 109.8m
F 19 100
F 20 11.2s
O 15.9994
O 13 8.7ms
O 14 71.0s
O 15 122s
O 16 99.759
O 17 0.037
O 18 0.204
O 19 26.8s
N 14.0067
N 12 11.0ms
N 13 9.99m
N 14 99.63
N 15 0.37
N 16 7.13s
N 17 4.14s
N 18 0.63s
C 12.01115
C 9 127ms
C 10 19.4s
C 11 20.4m
C 12 98.89
C 13 1.11
C 14 5730y
C 15 2.3s
C 16 0.74s
C17
B 10.811
B 8 774ms
B 9 ≥3x10⁻¹⁹s
B 10 19.8
B 11 80.2
B 12 20.4ms
B 13 19ms
B14
B15
Be 9.0122
Be 6 ≳3x10⁻²¹s
Be 7 53.3d
Be 8 ~1x10⁻¹⁶s
Be 9 100
Be 10 2.7x10⁶y
Be 11 13.7s
Be 12 11.4ms
Li 6.940
Li 5 ~10⁻²¹s
Li 6 7.56
Li 7 92.44
Li 8 850ms
Li 9 0.175s
Li11
He 4.0026
He 3 0.00013
He 4 ~100
He 5 2x10⁻²¹s
He 6 802ms
He 8 122ms
H 1.00797
H 1 99.985
H 2 0.015
H 3 12.33y
n 1 11.0m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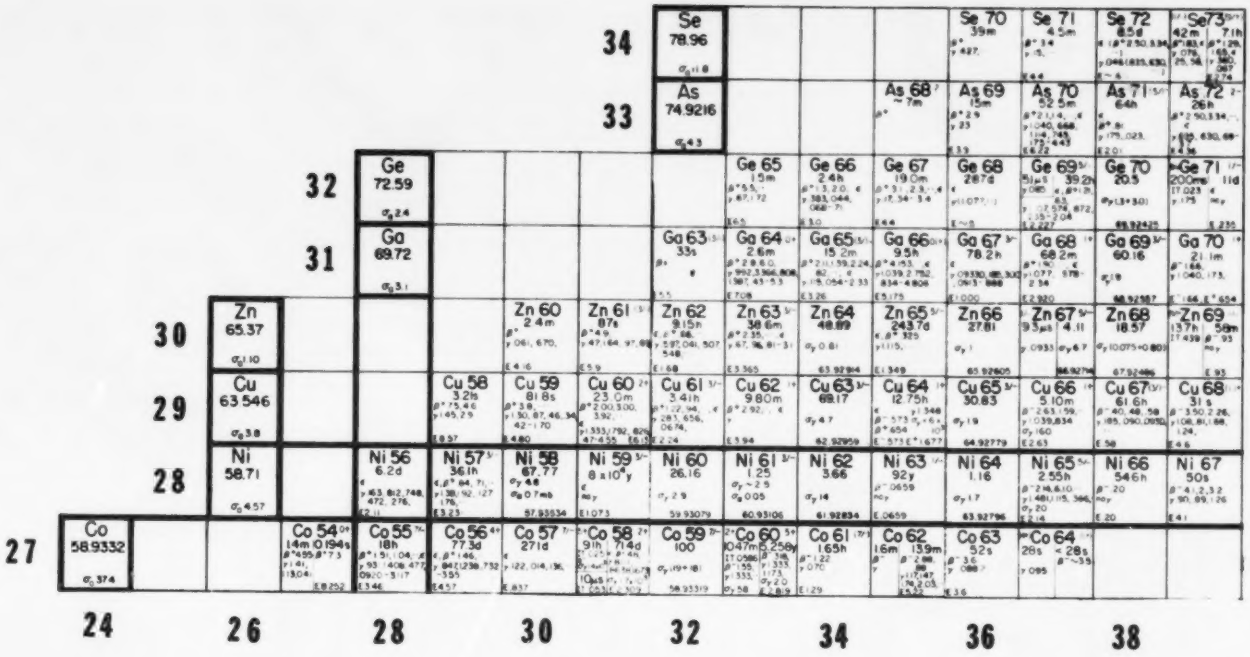
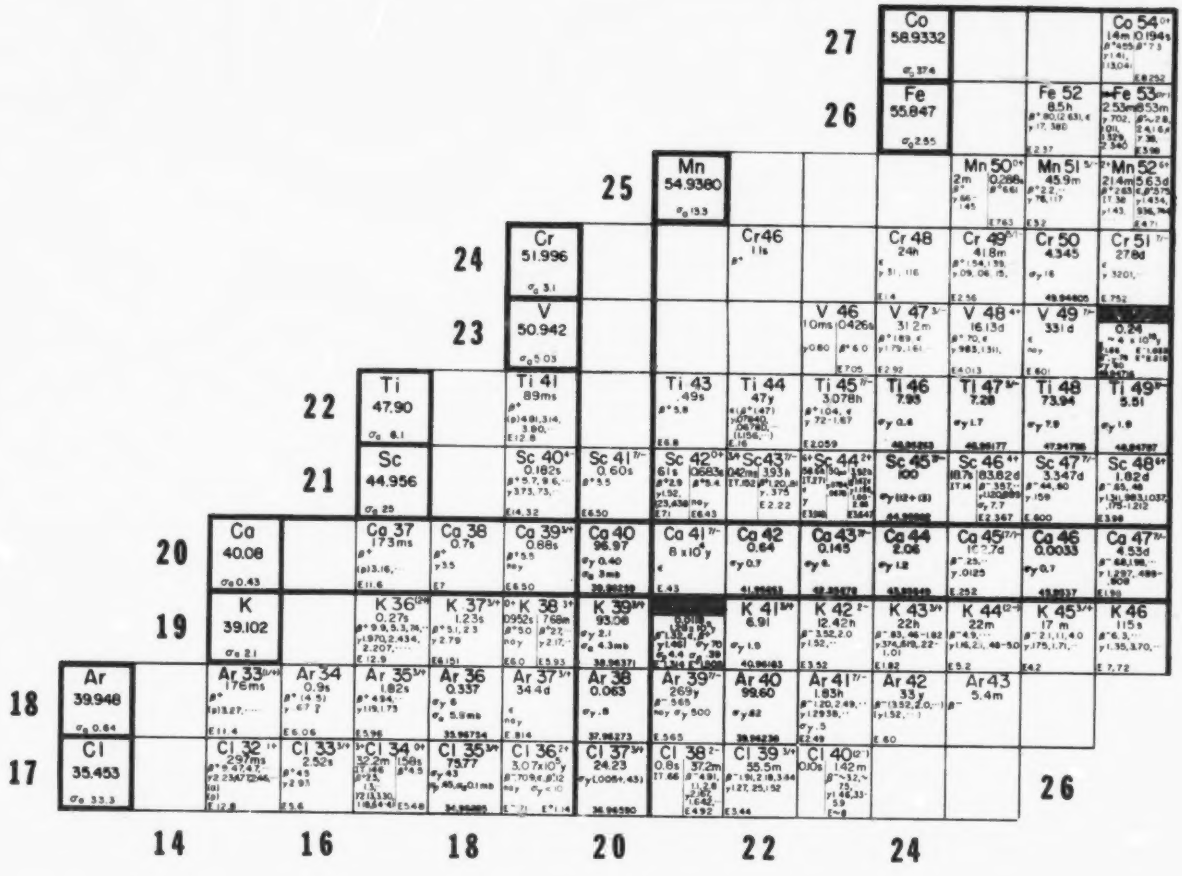
17
Ar
39.948
Cl
35.453
Ar 33
176ms
Ar 34
0.9s
Ar 35
1.82s
Ar 36
0.337
Ar 37
34.4d
Ar 38
0.063
Ar 39
269y
Ar 40
99.60
Ar 41
1.83h
Ar 42
33y
Ar 43
5.4m
Cl 32
297ms
Cl 33
2.52s
Cl 34
32.2m
1.56s
Cl 35
75.77
Cl 36
3.07x10⁵y
Cl 37
24.23
Cl 38
37.2m
Cl 39
55.5m
Cl 40
1.42m
26
S 29
0.19s
S 30
1.3s
S 31
2.64s
S 32
95.0
S 33
0.76
S 34
4.22
S 35
87.2d
S 36
0.014
S 37
5.06m
S 38
2.87h
24
P 28
270ms
P 29
4.23s
P 30
2.50m
P 31
100
P 32
14.31d
P 33
25.2d
P 34
12.4s
Si 26
2.1s
Si 27
4.20s
Si 28
92.21
Si 29
4.70
Si 30
3.09
Si 31
2.62h
Si 32
~650y
22
Al 25
7.23s
Al 26
7.4x10⁵y
Al 27
100
Al 28
2.27m
Al 29
6.52m
Al 30
3.3s
18
20
Mg 24
78.99
Mg 25
10.00
Mg 26
11.01
Mg 27
9.5m
Mg 28
21.3h
Na 23
100
Na 24
15.00h
Na 25
59s
Na 26
1.04s
Na 27
Ne 22
9.22
Ne 23
37.6s
Ne 24
3.38m
16
F 21
4.36s
F 22
4.0s
14
O 20
14s
O 21
N 19
12


34
Se 78.96
Se 70 39m
Se 71 4.5m
Se 72 8.5d
Se 73
33
As 74.9216
As 68 ~7m
As 69 15m
As 70 52.5m
As 71 64h
As 72 26h
32
Ge 72.59
Ge 65 15m
Ge 66 2.4h
Ge 67 19.0m
Ge 68 287d
Ge 69 39.2h
Ge 70 20.5
Ge 71 11d
31
Ga 69.72
Ga 63 33s
Ga 64 2.6m
Ga 65 15.2m
Ga 66 9.5h
Ga 67 78.2h
Ga 68 68.2m
Ga 69 60.16
Ga 70 21.1m
30
Zn 65.37
Zn 60 2.4m
Zn 61 87s
Zn 62 9.15h
Zn 63 38.6m
Zn 64 48.89
Zn 65 243.7d
Zn 66 27.81
Zn 67 4.11
Zn 68 18.57
Zn 69 13.7h 56m
29
Cu 63.546
Cu 58 3.21s
Cu 59 81.8s
Cu 60 23.0m
Cu 61 3.41h
Cu 62 9.80m
Cu 63 69.17
Cu 64 12.75h
Cu 65 30.83
Cu 66 5.10m
Cu 67 61.6h
Cu 68 31s
28
Ni 58.71
Ni 56 6.2d
Ni 57 36.1h
Ni 58 67.77
Ni 59 8x10⁴y
Ni 60 26.16
Ni 61 1.25
Ni 62 3.66
Ni 63 92y
Ni 64 1.16
Ni 65 2.55h
Ni 66 54.6h
Ni 67 50s
27
Co 58.9332
Co 54 14m 0.194s
Co 55 18h
Co 56 77.3d
Co 57 271d
Co 58 9.1h 71.4d
Co 59 100
Co 60 10.47m 5.258y
Co 61 1.65h
Co 62 16m 1.39m
Co 63 52s
Co 64 28s <28s
24
26
28
30
32
34
36
38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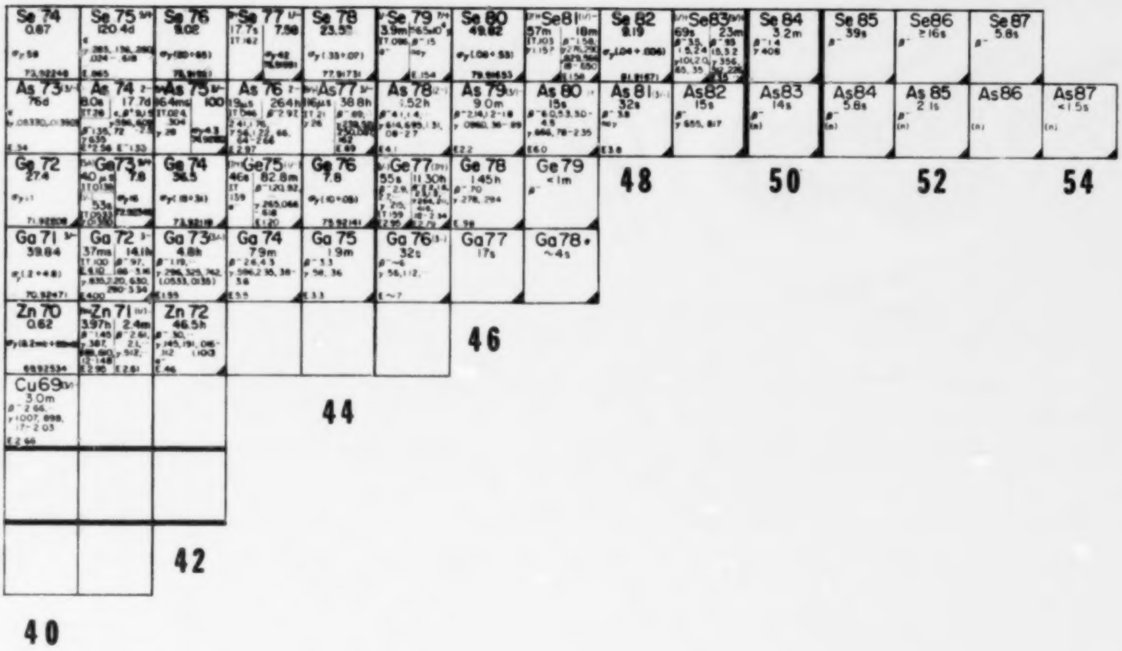
Co 58.9332
Co 54 14m 0.194s
26
Fe 55.847
Fe 52 8.5h
Fe 53 2.53m 8.53m
25
Mn 54.9380
Mn 50 2m 0.286s
Mn 51 45.9m
Mn 52 21.4m 5.63d
24
Cr 51.996
Cr 46 1.1s
Cr 48 24h
Cr 49 41.8m
Cr 50 4.345
Cr 51 27.8d
23
V 50.942
V 46 10ms 0.426s
V 47 31.2m
V 48 16.13d
V 49 331d
22
Ti 47.90
Ti 41 89ms
Ti 43 .49s
Ti 44 47y
Ti 45 3.078h
Ti 46 7.93
Ti 47 7.28
Ti 48 73.94
Ti 49 5.51
21
Sc 44.956
Sc 40 0.182s
Sc 41 0.60s
Sc 42 61s 0.683s
Sc 43 3.93h
Sc 44
Sc 45 100
Sc 46 83.82d
Sc 47 3.347d
Sc 48 1.82d
20
Ca 40.08
Ca 37 173ms
Ca 38 0.7s
Ca 39 0.88s
Ca 40 96.97
Ca 41 8x10⁴y
Ca 42 0.64
Ca 43 0.145
Ca 44 2.06
Ca 45 162.7d
Ca 46 0.0033
Ca 47 4.53d
19
K 39.102
K 36 0.27s
K 37 1.23s
K 38 0.952s 7.68m
K 39 93.08
K 41 6.91
K 42 12.42h
K 43 22h
K 44 22m
K 45 17m
K 46 115s
18
Ar 39.948
Ar 33 176ms
Ar 34 0.9s
Ar 35 1.82s
Ar 36 0.337
Ar 37 34.4d
Ar 38 0.063
Ar 39 269y
Ar 40 99.60
Ar 41 1.83h
Ar 42 33y
Ar 43 5.4m
17
Cl 35.453
Cl 32 297ms
Cl 33 2.52s
Cl 34 32.2m 1.58s
Cl 35 75.77
Cl 36 3.07x10⁵y
Cl 37 24.23
Cl 38 0.8s 37.2m
Cl 39 55.5m
Cl 40 1.42m
14
16
18
20
22
24
26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Se 75
Se 76
Se 77
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Se 79
Se 80
Se 81
Se 82
Se 83
Se 84
Se 85
Se 86
Se 87
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As 75
As 76
As 77
As 78
As 79
As 80
As 81
As 82
As 83
As 84
As 85
As 86
As 87
Ge 72
Ge 73
Ge 74
Ge 75
Ge 76
Ge 77
Ge 78
Ge 79
Ga 71
Ga 72
Ga 73
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54
46
44
42
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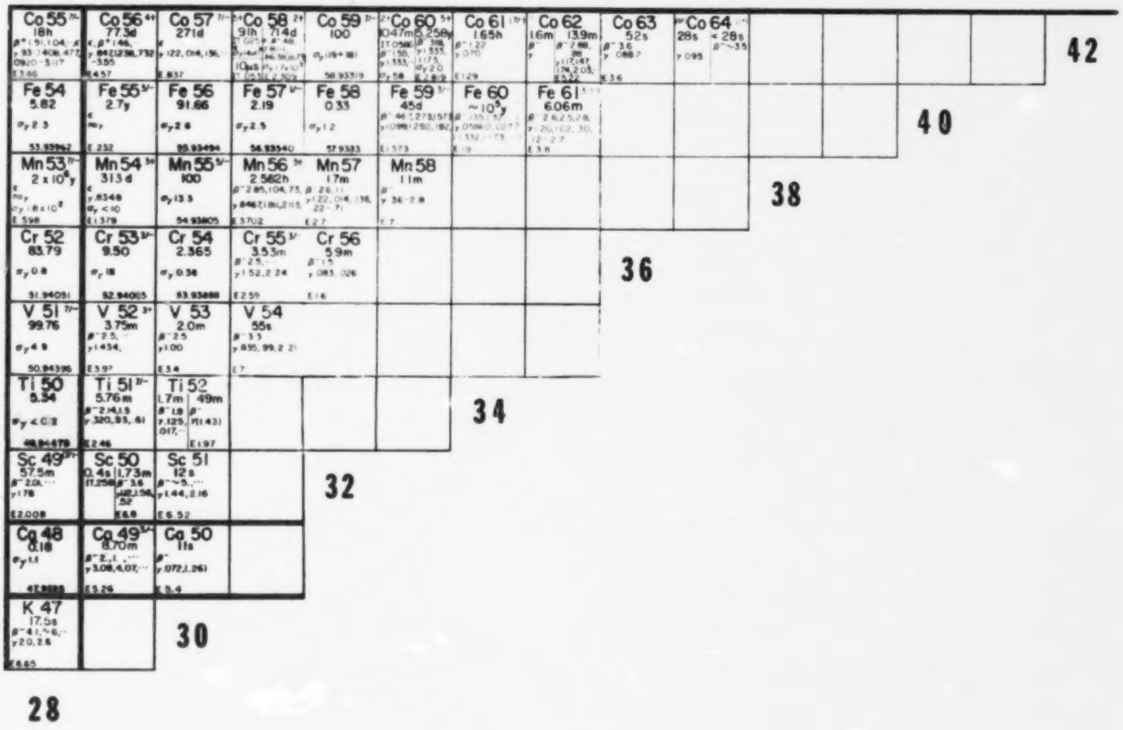
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Co 56
Co 57
Co 58
Co 59
Co 60
Co 61
Co 62
Co 63
Co 64
Fe 54
Fe 55
Fe 56
Fe 57
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Fe 60
Fe 61
Mn 53
Mn 54
Mn 55
Mn 56
Mn 57
Mn 58
Cr 52
Cr 53
Cr 54
Cr 55
Cr 56
V 51
V 52
V 53
V 54
Ti 50
Ti 51
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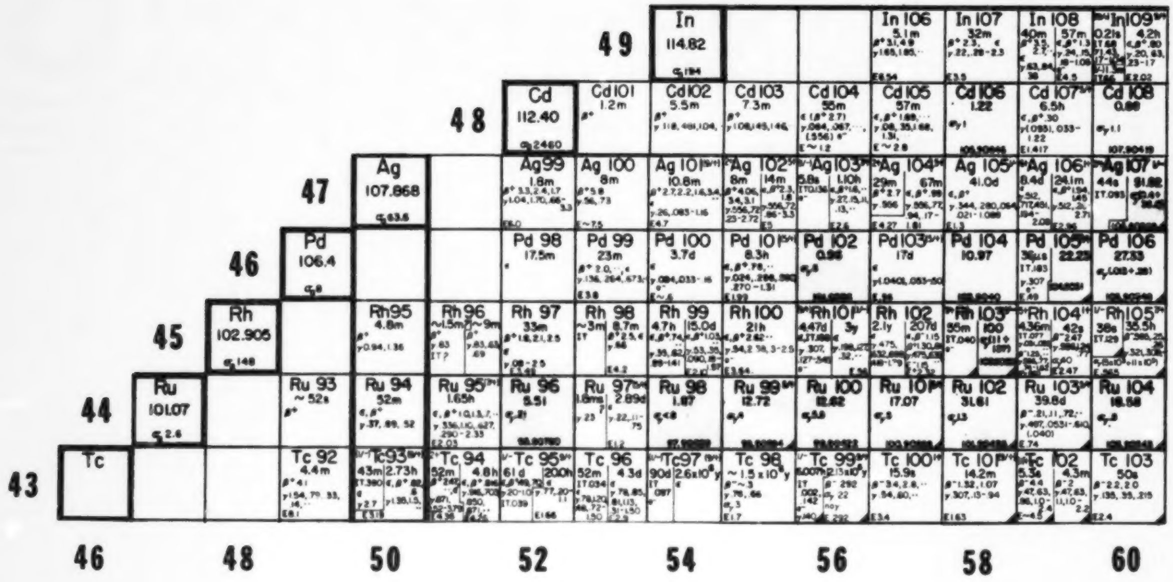
36
34
32
30
28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In 114.82
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Cd 112.40
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Ag 107.868
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Pd 106.4
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Rh 102.905
44
Ru 101.07
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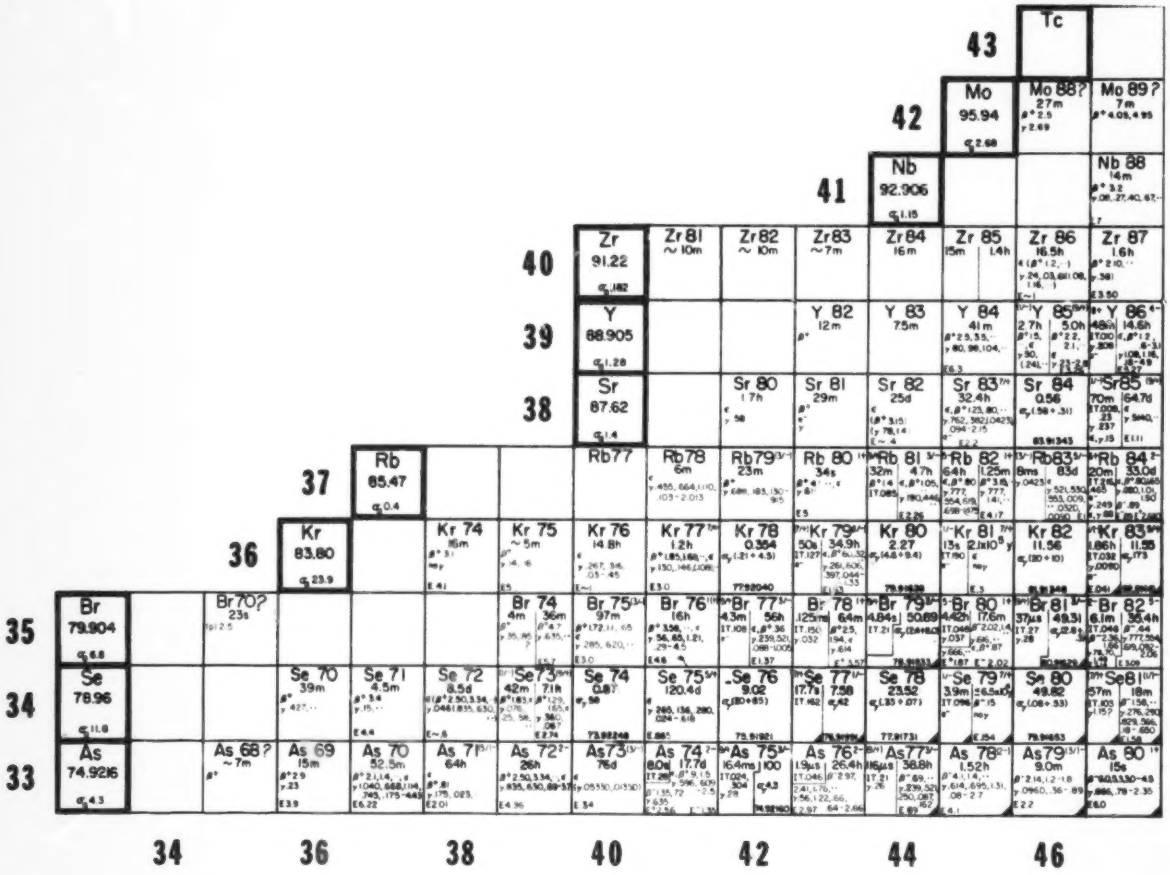
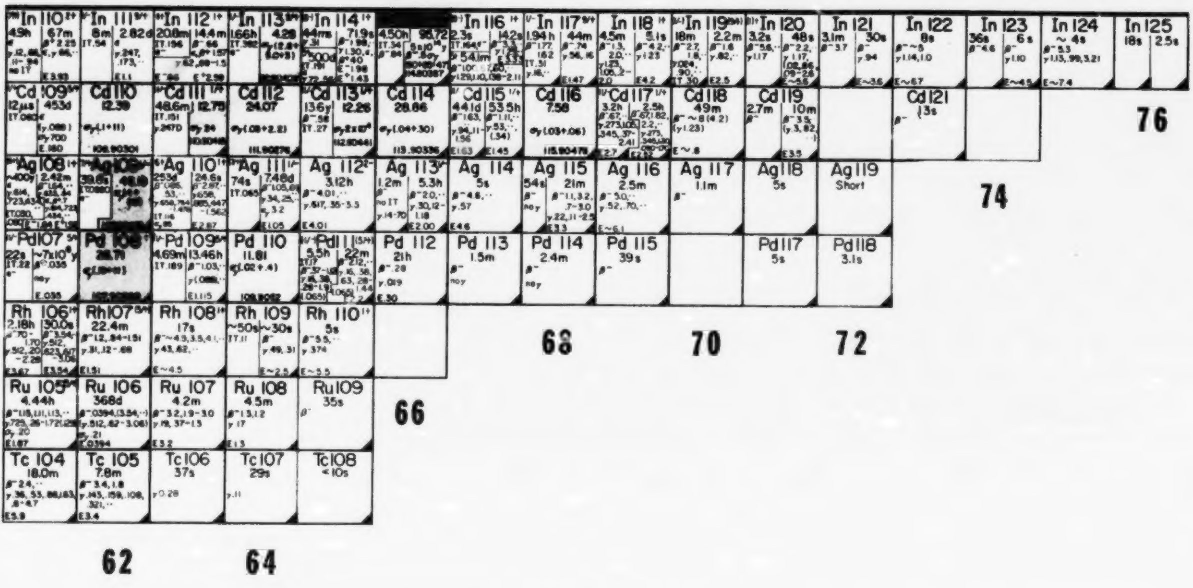
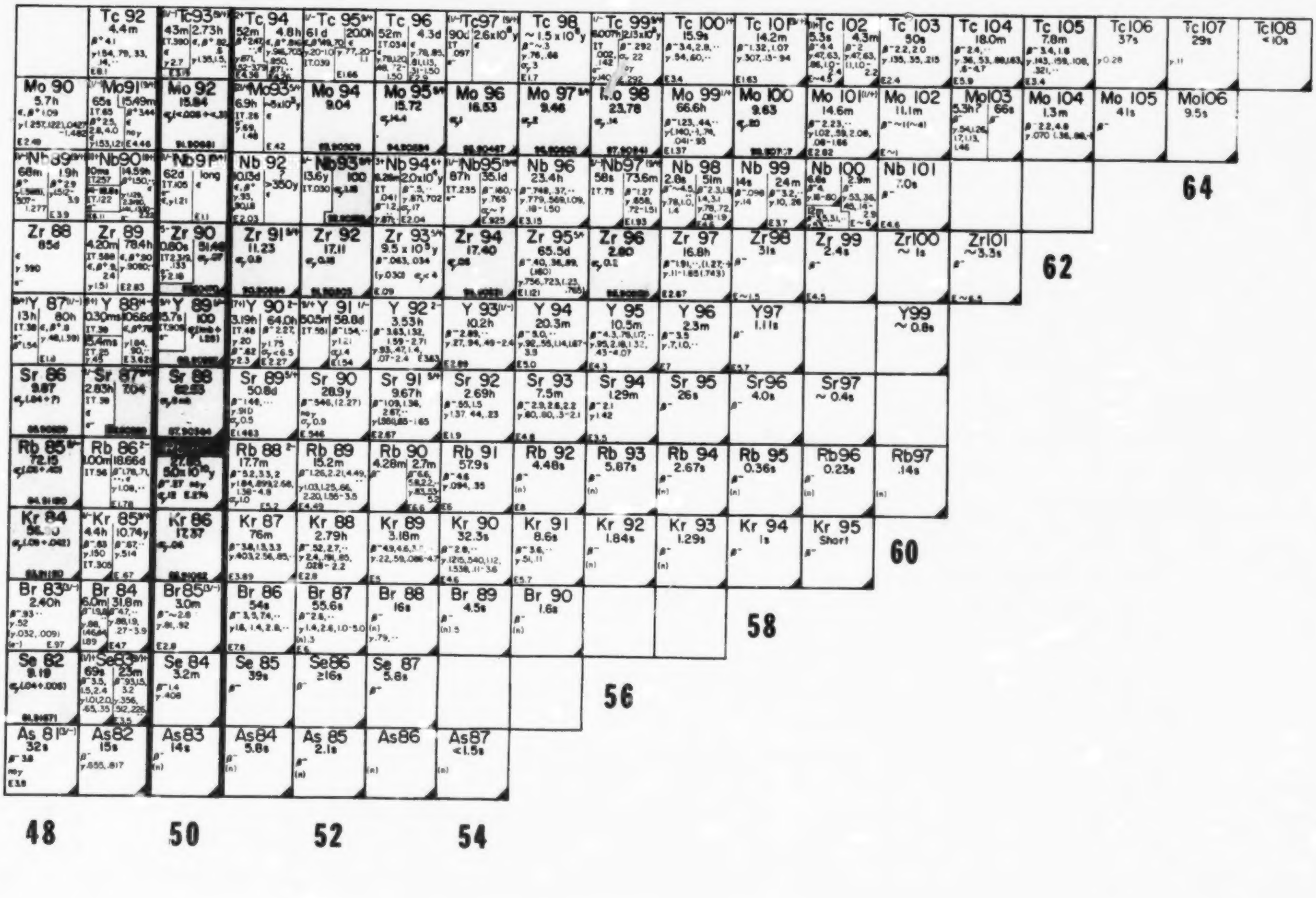
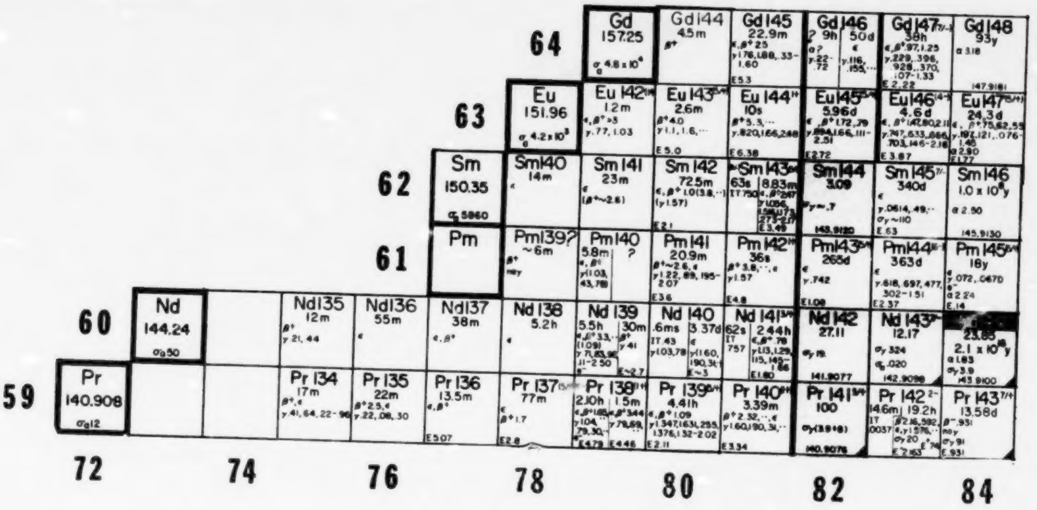
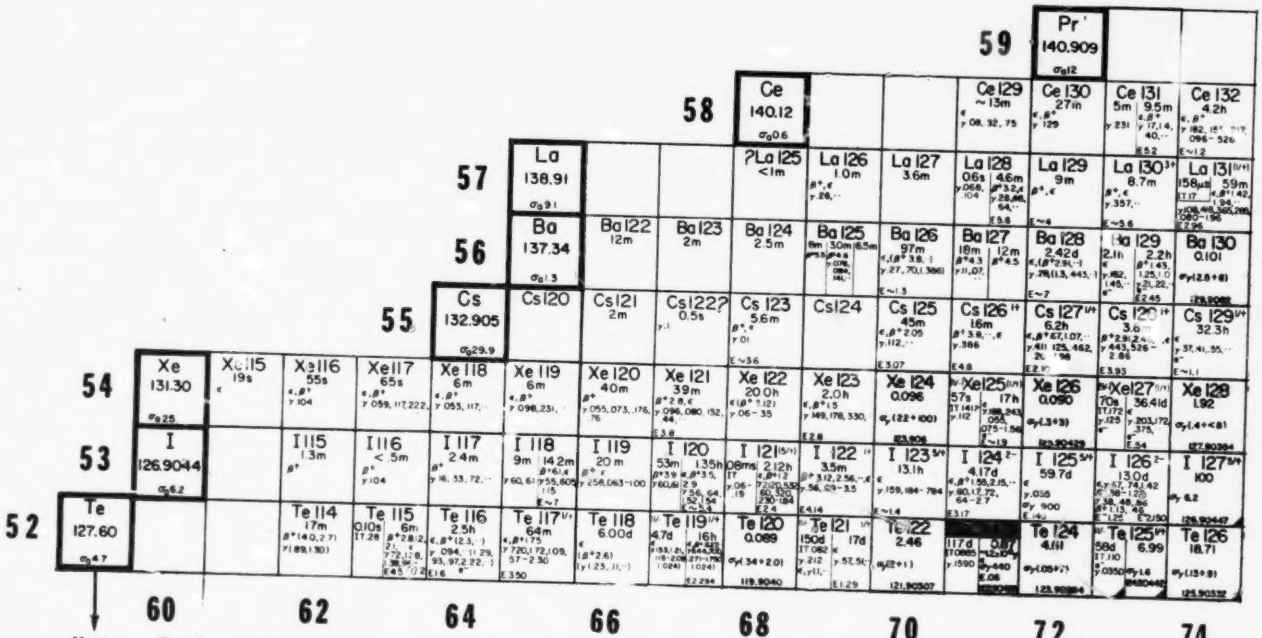
Tc
In 106
In 107
In 108
In 109
Cd 101
Cd 102
Cd 103
Cd 104
Cd 105
Cd 106
Cd 107
Cd 108
Ag 99
Ag 100
Ag 101
Ag 102
Ag 103
Ag 104
Ag 105
Ag 106
Ag 107
Pd 98
Pd 99
Pd 100
Pd 101
Pd 102
Pd 103
Pd 104
Pd 105
Pd 106
Rh 95
Rh 96
Rh 97
Rh 98
Rh 99
Rh 100
Rh 101
Rh 102
Rh 103
Rh 104
Rh 105
Ru 93
Ru 94
Ru 95
Ru 96
Ru 97
Ru 98
Ru 99
Ru 100
Ru 101
Ru 102
Ru 103
Ru 104
Tc 92
Tc 93
Tc 94
Tc 95
Tc 96
Tc 97
Tc 98
Tc 99
Tc 100
Tc 101
Tc 102
Tc 103
46
48
50
52
54
56
58
60


43
Tc
42
Mo 95.94
Mo 88?
Mo 89?
41
Nb 92.906
Nb 88
40
Zr 91.22
Zr 81
Zr 82
Zr 83
Zr 84
Zr 85
Zr 86
Zr 87
39
Y 88.905
Y 82
Y 83
Y 84
Y 85
Y 86
38
Sr 87.62
Sr 80
Sr 81
Sr 82
Sr 83
Sr 84
Sr 85
37
Rb 85.47
Rb 77
Rb 78
Rb 79
Rb 80
Rb 81
Rb 82
Rb 83
Rb 84
36
Kr 83.80
Kr 74
Kr 75
Kr 76
Kr 77
Kr 78
Kr 79
Kr 80
Kr 81
Kr 82
Kr 83
35
Br 79.904
Br 70?
Br 74
Br 75
Br 76
Br 77
Br 78
Br 79
Br 80
Br 81
Br 82
34
Se 78.96
Se 70
Se 71
Se 72
Se 73
Se 74
Se 75
Se 76
Se 77
Se 78
Se 79
Se 80
Se 81
33
As 74.9216
As 68?
As 69
As 70
As 71
As 72
As 73
As 74
As 75
As 76
As 77
As 78
As 79
As 80
34
36
38
40
42
44
46

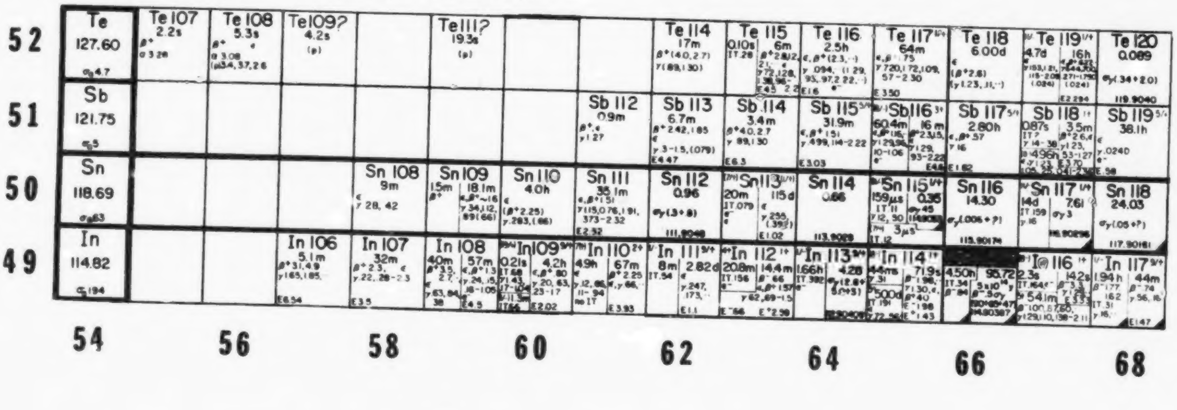

In 110
In 111
In 112
In 113
In 114
In 116
In 117
In 118
In 119
In 120
In 121
In 122 8s
In 123
In 124 ~4s
In 125 18s 2.5s
Cd 109 453d
Cd 110 12.39
Cd 111 48.6m 12.75
Cd 112 24.07
Cd 113 13.6y 12.26
Cd 114 28.86
Cd 115 44.1d 53.5h
Cd 116 7.58
Cd 117 3.2h 2.5h
Cd 118 49m
Cd 119 2.7m 10m
Cd 121 13s
Ag 108 2.42m
Ag 109
Ag 110 253d 24.6s
Ag 111 74s 7.48d
Ag 112 3.12h
Ag 113 1.2m 5.3h
Ag 114 5s
Ag 115 21m
Ag 116 2.5m
Ag 117 1.1m
Ag 118 5s
Ag 119 Short
Pd 107
Pd 108 26.71
Pd 109 4.69m 13.46h
Pd 110 11.81
Pd 111 5.5h 22m
Pd 112 21h
Pd 113 1.5m
Pd 114 2.4m
Pd 115 39s
Pd 117 5s
Pd 118 3.1s
Rh 106 2.18h 30.0s
Rh 107 22.4m
Rh 108 17s
Rh 109 ~50s ~30s
Rh 110 5s
Ru 105 4.44h
Ru 106 368d
Ru 107 4.2m
Ru 108 4.5m
Ru 109 35s
Tc 104 18.0m
Tc 105 7.8m
Tc 106 37s
Tc 107 29s
Tc 108 <10s
62
64
66
68
70
72
74
76

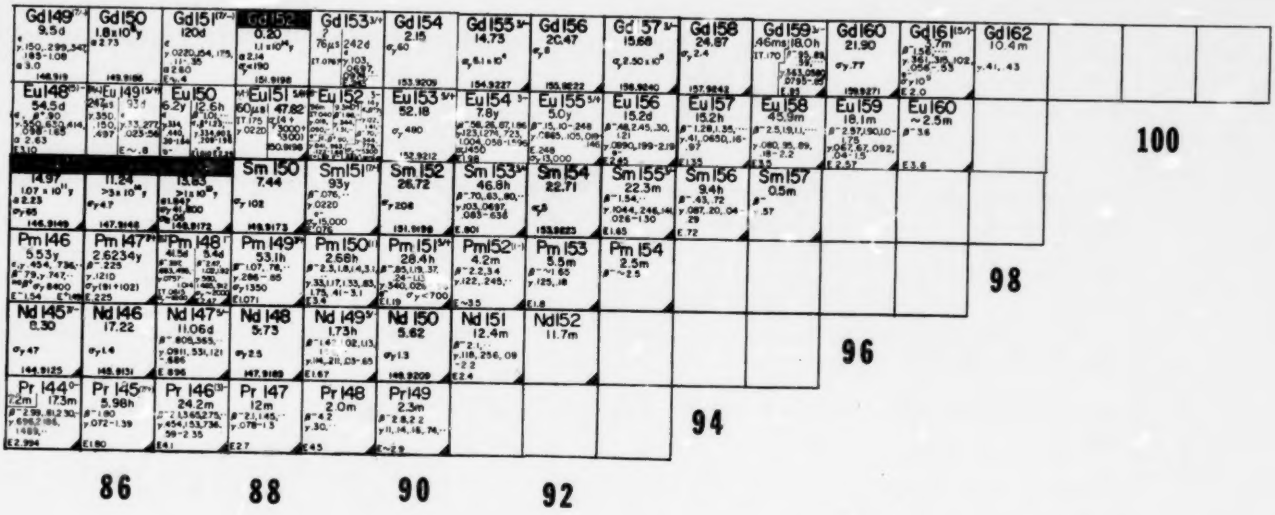

Tc 92 4.4m
Tc 93 43m 2.73h
Tc 94 52m 4.8h
Tc 95 61d 20.0h
Tc 96 52m 4.3d
Tc 97 90d 2.6x10⁶y
Tc 98 ~1.5x10⁶y
Tc 99 2.13x10⁵y
Tc 100 15.9s
Tc 101 14.2m
Tc 102 5.3s 4.3m
Tc 103 50s
Tc 104 18.0m
Tc 105 7.8m
Tc 106 37s
Tc 107 29s
Tc 108 <10s
Mo 90 5.7h
Mo 91 65s 15.49m
Mo 92 15.84
Mo 93 6.9h
Mo 94 9.04
Mo 95 15.72
Mo 96 16.53
Mo 97 9.46
Mo 98 23.78
Mo 99 66.6h
Mo 100 9.63
Mo 101 14.6m
Mo 102 11.1m
Mo 103 66s
Mo 104 1.3m
Mo 105 41s
Mo 106 9.5s
Nb 89 68m 1.9h
Nb 90 14.59h
Nb 91 62d long
Nb 92 10.13d
Nb 93 13.6y 100
Nb 94 2.0x10⁴y
Nb 95 87h 35.1d
Nb 96 23.4h
Nb 97 58s 73.6m
Nb 98 2.8s 51m
Nb 99 14s 2.4m
Nb 100
Nb 101 7.0s
Zr 88 85d
Zr 89 4.20m 78.4h
Zr 90 0.80s 51.46
Zr 91 11.23
Zr 92 17.11
Zr 93 9.5x10⁵y
Zr 94 17.40
Zr 95 65.5d
Zr 96 2.80
Zr 97 16.8h
Zr 98 31s
Zr 99 2.4s
Zr 100 ~1s
Zr 101 ~3.3s
Y 87 13h 80h
Y 88 106.6d
Y 89 100
Y 90 3.19h 64.0h
Y 91 50.5m 58.8d
Y 92 3.53h
Y 93 10.2h
Y 94 20.3m
Y 95 10.5m
Y 96 2.3m
Y 97 1.11s
Y 99 ~0.8s
Sr 86 9.87
Sr 87 2.83h 7.04
Sr 88 82.53
Sr 89 50.8d
Sr 90 28.9y
Sr 91 9.67h
Sr 92 2.69h
Sr 93 7.5m
Sr 94 1.29m
Sr 95 26s
Sr 96 4.0s
Sr 97 ~0.4s
Rb 85 72.15
Rb 86 1.00m 18.66d
Rb 87 27.85
Rb 88 17.7m
Rb 89 15.2m
Rb 90 4.28m 2.7m
Rb 91 57.9s
Rb 92 4.48s
Rb 93 5.87s
Rb 94 2.67s
Rb 95 0.36s
Rb 96 0.23s
Rb 97 .14s
Kr 84 56.90
Kr 85 4.4h 10.74y
Kr 86 17.37
Kr 87 76m
Kr 88 2.79h
Kr 89 3.18m
Kr 90 32.3s
Kr 91 8.6s
Kr 92 1.84s
Kr 93 1.29s
Kr 94 1s
Kr 95 Short
Br 83 2.40h
Br 84 6.0m 31.8m
Br 85 3.0m
Br 86 54s
Br 87 55.6s
Br 88 16s
Br 89 4.5s
Br 90 1.6s
Se 82 9.19
Se 83 69s 23m
Se 84 3.2m
Se 85 39s
Se 86 ≥16s
Se 87 5.8s
As 81 32s
As 82 15s
As 83 14s
As 84 5.8s
As 85 2.1s
As 86
As 87 <1.5s
48
50
52
54
56
58
60
62
64


64
Gd 157.25
Gd 144 4.5m
Gd 145 22.9m
Gd 146
Gd 147 38h
Gd 148 93y
63
Eu 151.96
Eu 142 1.2m
Eu 143 2.6m
Eu 144 10s
Eu 145 5.96d
Eu 146 4.6d
Eu 147 24.3d
62
Sm 150.35
Sm 140 14m
Sm 141 23m
Sm 142 72.5m
Sm 143 63s 8.83m
Sm 144 3.09
Sm 145 340d
Sm 146 1.0 x 10⁸y
61
Pm
Pm 139? ~6m
Pm 140 5.8m ?
Pm 141 20.9m
Pm 142 36s
Pm 143 265d
Pm 144 363d
Pm 145 18y
60
Nd 144.24
Nd 135 12m
Nd 136 55m
Nd 137 38m
Nd 138 5.2h
Nd 139 5.5h 30m
Nd 140 3.37d
Nd 141 62s 2.44h
Nd 142 27.11
Nd 143 12.17
Nd 144 23.85 2.1 x 10¹⁵y
59
Pr 140.908
Pr 134 17m
Pr 135 22m
Pr 136 13.5m
Pr 137 77m
Pr 138 2.10h 1.5m
Pr 139 4.41h
Pr 140 3.39m
Pr 141 100
Pr 142 14.6m 19.2h
Pr 143 13.58d
72
74
76
78
80
82
84


59
Pr 140.909
58
Ce 140.12
Ce 129 ~13m
Ce 130 27m
Ce 131 5m 9.5m
Ce 132 4.2h
57
La 138.91
?La 125 <1m
La 126 1.0m
La 127 3.6m
La 128
La 129 9m
La 130 8.7m
La 131 59m
56
Ba 137.34
Ba 122 12m
Ba 123 2m
Ba 124 2.5m
Ba 125
Ba 126 97m
Ba 127 12m
Ba 128 2.42d
Ba 129 2.2h
Ba 130 0.101
55
Cs 132.905
Cs 120
Cs 121 2m
Cs 122? 0.5s
Cs 123 5.6m
Cs 124
Cs 125 45m
Cs 126 1.6m
Cs 127 6.2h
Cs 128 3.6m
Cs 129 32.3h
54
Xe 131.30
Xe 115 19s
Xe 116 55s
Xe 117 65s
Xe 118 6m
Xe 119 6m
Xe 120 40m
Xe 121 39m
Xe 122 20.0h
Xe 123 2.0h
Xe 124 0.096
Xe 125 17h
Xe 126 0.090
Xe 127 36.4d
Xe 128 1.92
53
I 126.9044
I 115 1.3m
I 116 <.5m
I 117 2.4m
I 118 9m 14.2m
I 119 20m
I 120 53m 1.35h
I 121 2.12h
I 122 3.5m
I 123 13.1h
I 124 4.17d
I 125 59.7d
I 126 13.0d
I 127 100
52
Te 127.60
Te 114 17m
Te 115 6m
Te 116 2.5h
Te 117 64m
Te 118 6.00d
Te 119 4.7d 16h
Te 120 0.089
Te 121 150d 17d
Te 122 2.46
Te 124 4.61
Te 125 58d 6.99
Te 126 18.71
60
62
64
66
68
70
72
74

Note - Te incomplete here, complete below.


52
Te 127.60
Te 107 2.2s
Te 108 5.3s
Te 109? 4.2s
Te 111? 19.3s
Te 114 17m
Te 115 6m
Te 116 2.5h
Te 117 64m
Te 118 6.00d
Te 119 4.7d 16h
Te 120 0.089
51
Sb 121.75
Sb 112 0.9m
Sb 113 6.7m
Sb 114 3.4m
Sb 115 31.9m
Sb 116 60.4m 16m
Sb 117 2.80h
Sb 118 3.5m
Sb 119 38.1h
50
Sn 118.69
Sn 108 9m
Sn 109 18.1m
Sn 110 4.0h
Sn 111 35.1m
Sn 112 0.96
Sn 113 115d
Sn 114 0.66
Sn 115 0.35
Sn 116 14.30
Sn 117 7.61
Sn 118 24.03
49
In 114.82
In 106 5.1m
In 107 32m
In 108 40m 57m
In 109 4.2h
In 110 4.9h 67m
In 111 2.82d
In 112 20.8m 14.4m
In 113 4.28
In 114 72s
In 115 95.72
In 116 54m
In 117 1.94h 44m
54
56
58
60
62
64
66
68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Gd150
Gd151
Gd152
Gd153
Gd154
Gd155
Gd156
Gd157
Gd158
Gd159
Gd160
Gd161
Gd162
Eu148
Eu149
Eu150
Eu151
Eu152
Eu153
Eu154
Eu155
Eu156
Eu157
Eu158
Eu159
Eu160
Sm150
Sm151
Sm152
Sm153
Sm154
Sm155
Sm156
Sm157
Pm146
Pm147
Pm148
Pm149
Pm150
Pm151
Pm152
Pm153
Pm154
Nd145
Nd146
Nd147
Nd148
Nd149
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Pr149
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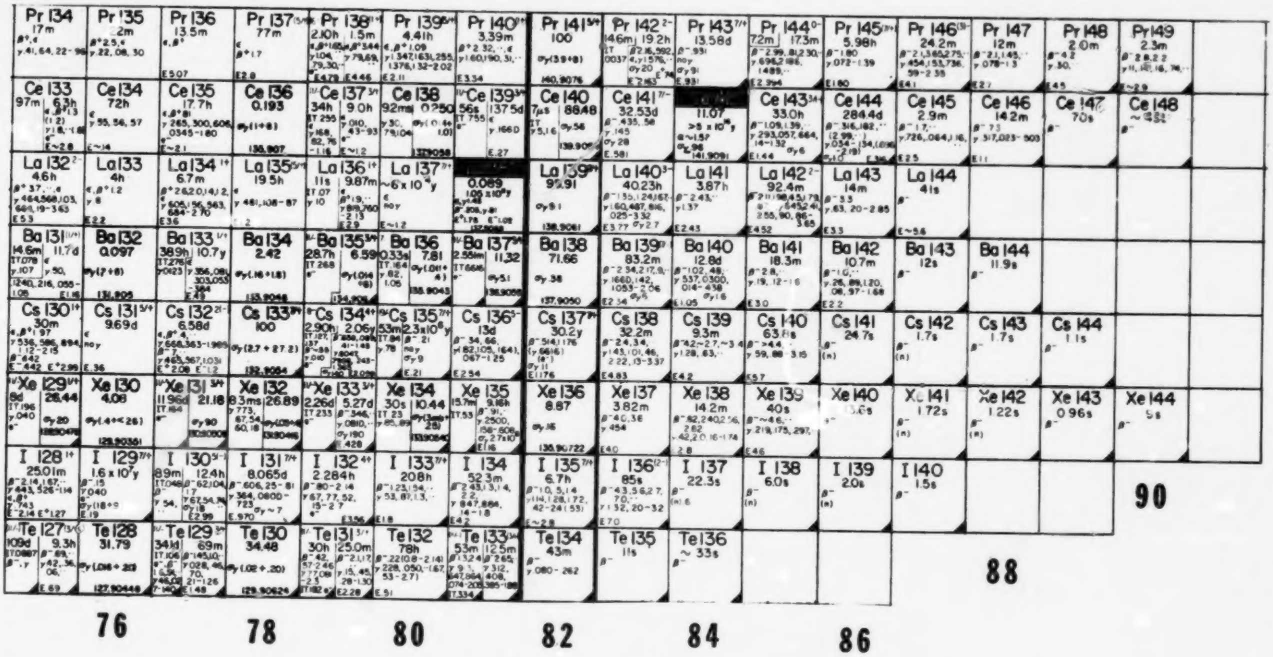
88
90
92
94
96
98
100


Pr134
Pr135
Pr136
Pr137
Pr138
Pr139
Pr140
Pr141
Pr142
Pr143
Pr144
Pr145
Pr146
Pr147
Pr148
Pr149
Ce133
Ce134
Ce135
Ce136
Ce137
Ce138
Ce139
Ce140
Ce141
Ce143
Ce144
Ce145
Ce146
Ce147
Ce148
La132
La133
La134
La135
La136
La137
La139
La140
La141
La142
La143
La144
Ba131
Ba132
Ba133
Ba134
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Ba138
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Ba141
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Ba144
Cs130
Cs131
Cs132
Cs133
Cs134
Cs135
Cs136
Cs137
Cs138
Cs139
Cs140
Cs141
Cs142
Cs143
Cs144
Xe129
Xe130
Xe131
Xe132
Xe133
Xe134
Xe135
Xe136
Xe137
Xe138
Xe139
Xe140
Xe141
Xe142
Xe143
Xe144
I128
I129
I130
I131
I132
I133
I134
I135
I136
I137
I138
I139
I140
Te127
Te128
Te129
Te130
Te131
Te132
Te133
Te134
Te135
Te136
76
78
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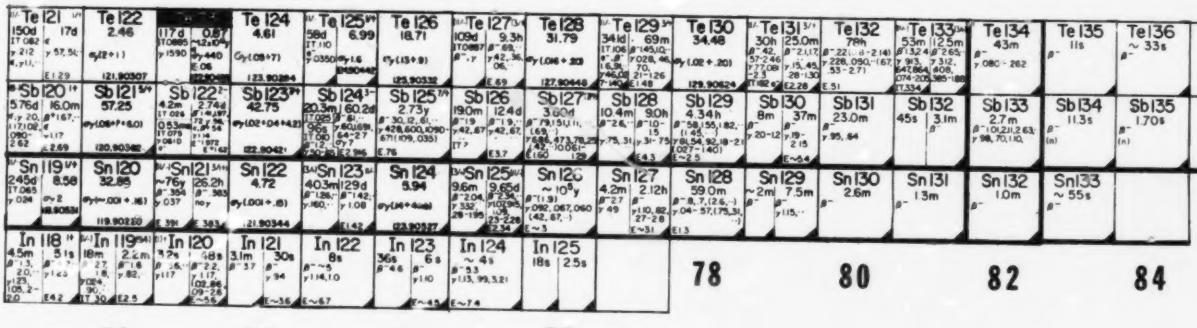
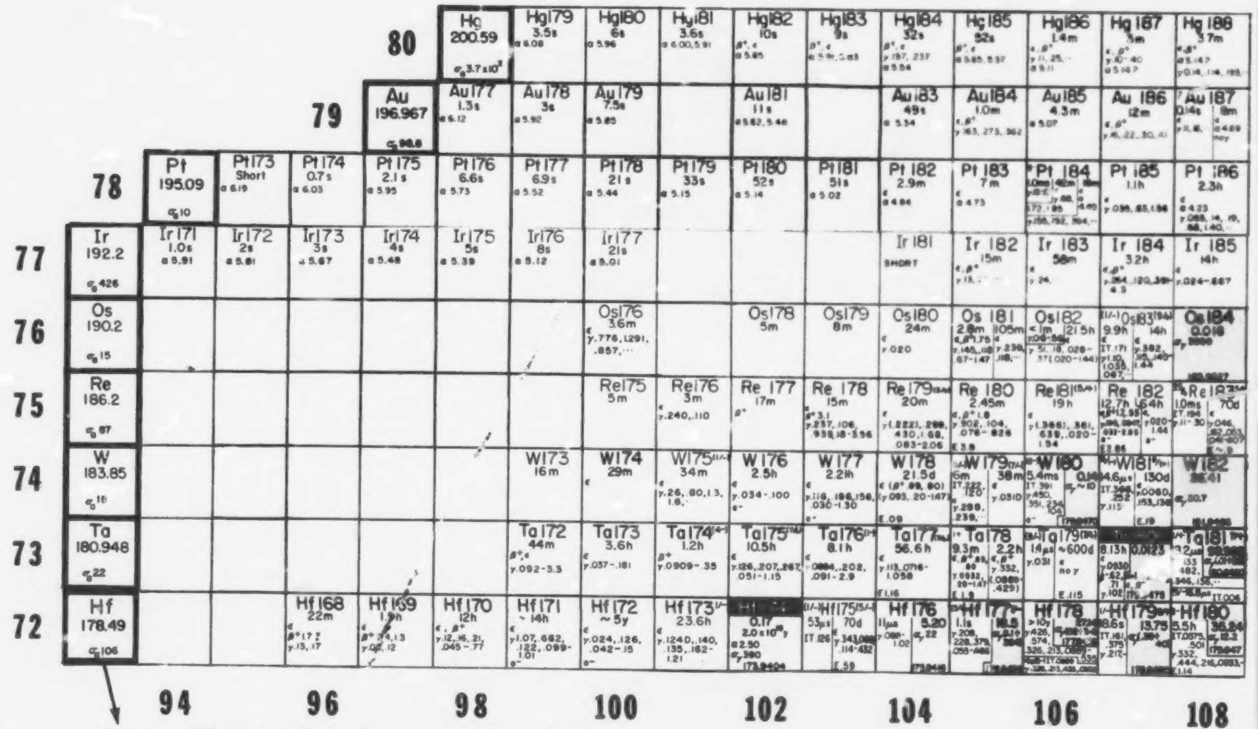
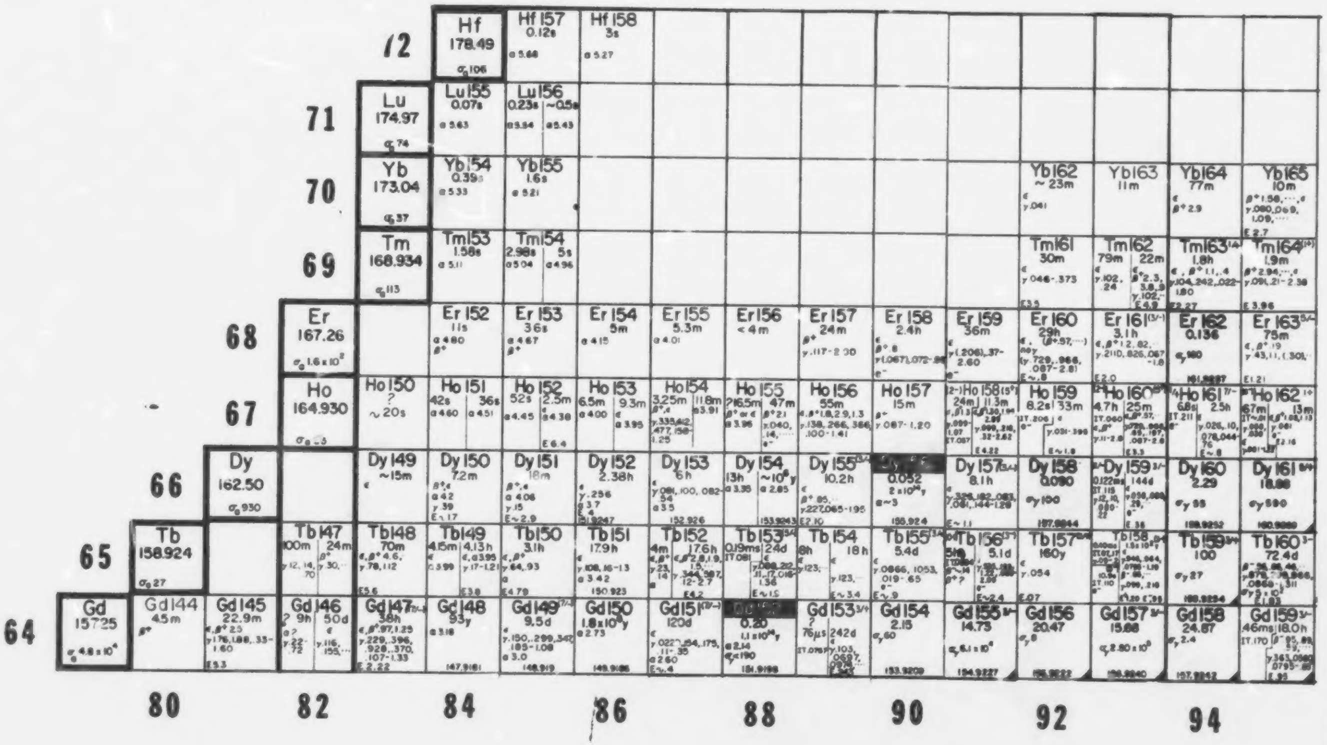
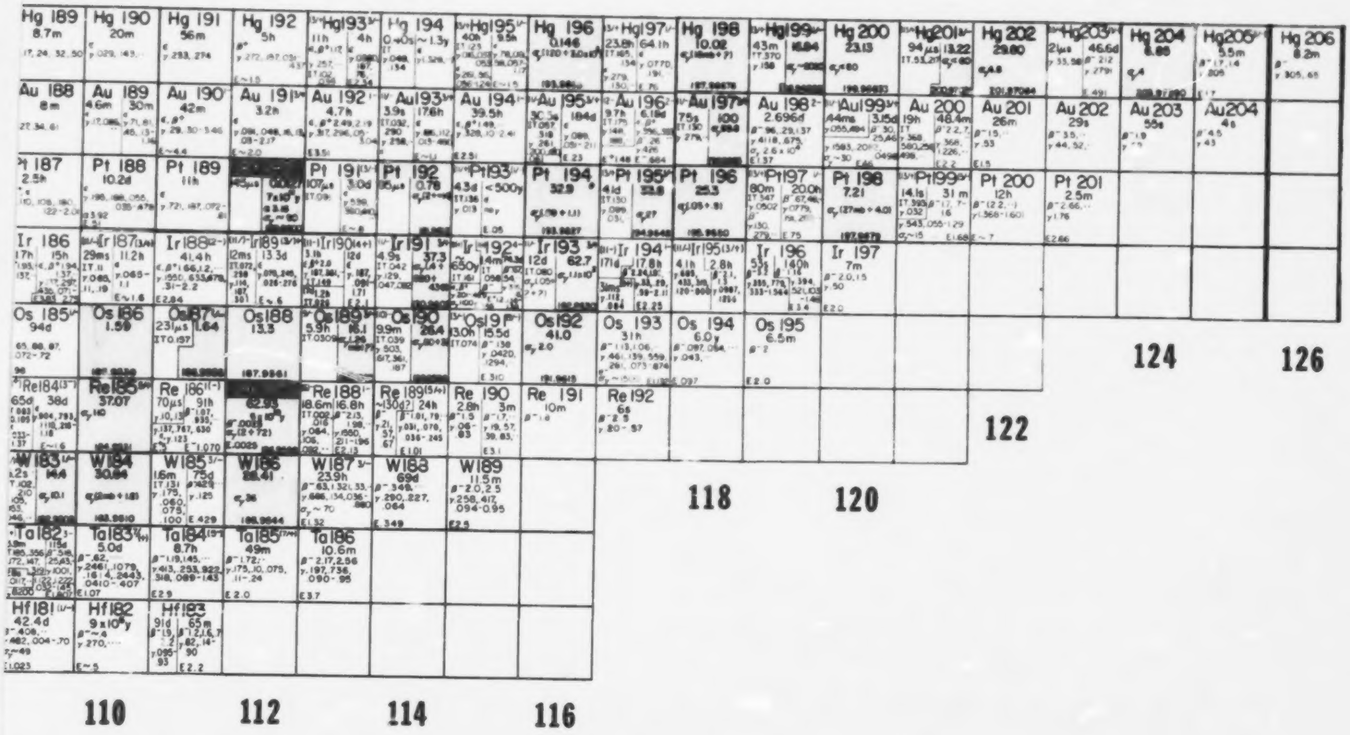
86
88
90


Te121
Te122
Te124
Te125
Te126
Te127
Te128
Te129
Te130
Te131
Te132
Te133
Te134
Te135
Te136
Sb120
Sb121
Sb122
Sb123
Sb124
Sb125
Sb126
Sb127
Sb128
Sb129
Sb130
Sb131
Sb132
Sb133
Sb134
Sb135
Sn119
Sn120
Sn121
Sn122
Sn123
Sn124
Sn125
Sn126
Sn127
Sn128
Sn129
Sn130
Sn131
Sn132
Sn133
In118
In119
In120
In121
In122
In123
In124
In125
70
72
74
76
78
80
82
84


80
Hg 200.59
79
Au 196.967
78
Pt 195.09
77
Ir 192.2
76
Os 190.2
75
Re 186.2
74
W 183.85
73
Ta 180.948
72
Hf 178.49
94
96
98
100
102
104
106
108

Note - Hf incomplete here, complete below.


72
Hf 178.49
71
Lu 174.97
70
Yb 173.04
69
Tm 168.934
68
Er 167.26
67
Ho 164.930
66
Dy 162.50
65
Tb 158.924
64
Gd 157.25
80
82
84
86
88
90
92
94


Hg 189
Hg 190
Hg 191
Hg 192
Hg 193
Hg 194
Hg 195
Hg 196
Hg 197
Hg 198
Hg 199
Hg 200
Hg 201
Hg 202
Hg 203
Hg 204
Hg 205
Hg 206
Au 188
Au 189
Au 190
Au 191
Au 192
Au 193
Au 194
Au 195
Au 196
Au 197
Au 198
Au 199
Au 200
Au 201
Au 202
Au 203
Au 204
Pt 187
Pt 188
Pt 189
Pt 191
Pt 192
Pt 193
Pt 194
Pt 195
Pt 196
Pt 197
Pt 198
Pt 199
Pt 200
Pt 201
Ir 186
Ir 187
Ir 188
Ir 189
Ir 190
Ir 191
Ir 192
Ir 193
Ir 194
Ir 195
Ir 196
Ir 197
Os 185
Os 186
Os 187
Os 188
Os 189
Os 190
Os 191
Os 192
Os 193
Os 194
Os 195
Re 184
Re 185
Re 186
Re 188
Re 189
Re 190
Re 191
Re 192
W 183
W 184
W 185
W 186
W 187
W 188
W 189
Ta 182
Ta 183
Ta 184
Ta 185
Ta 186
Hf 181
Hf 182
Hf 183
110
112
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120
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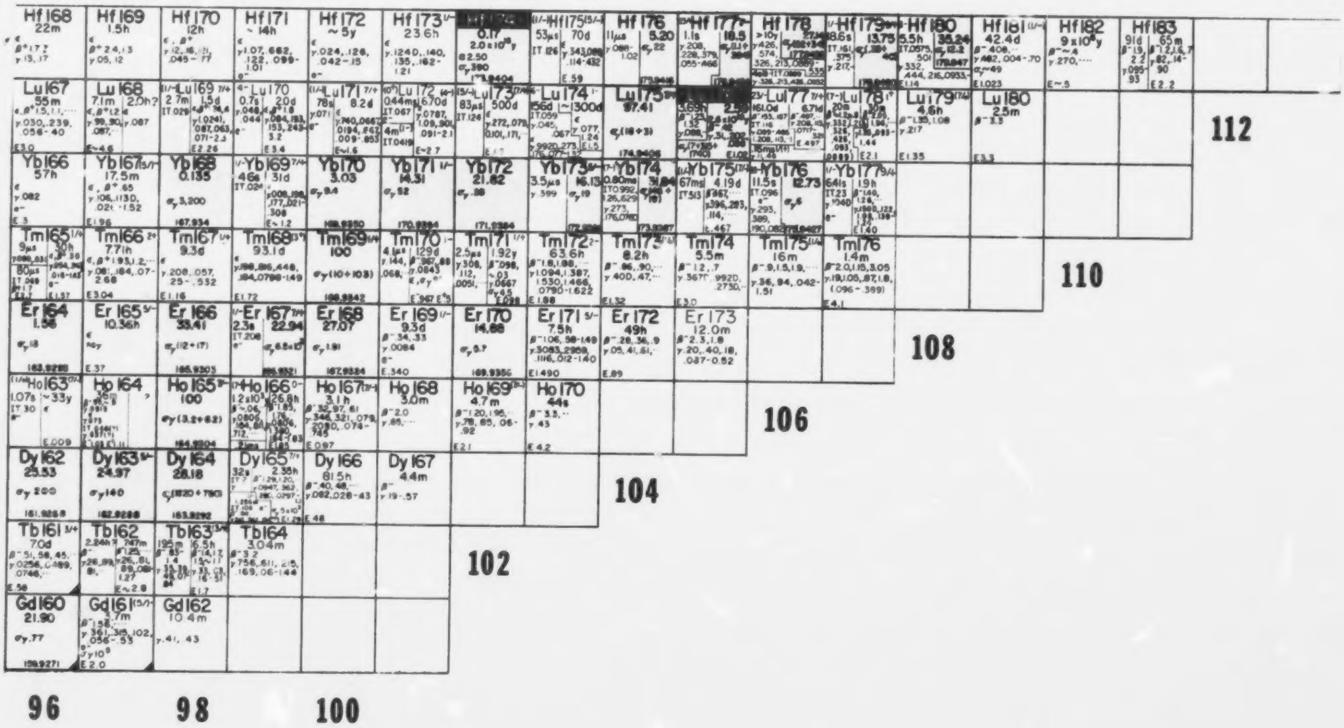
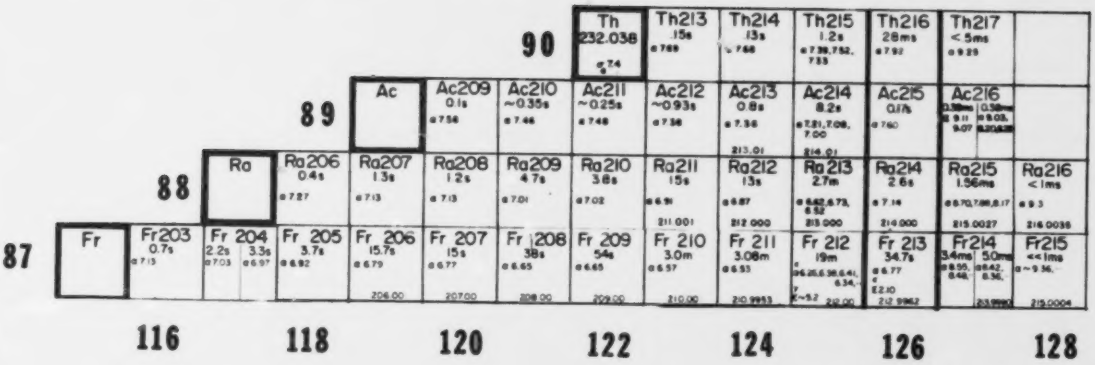
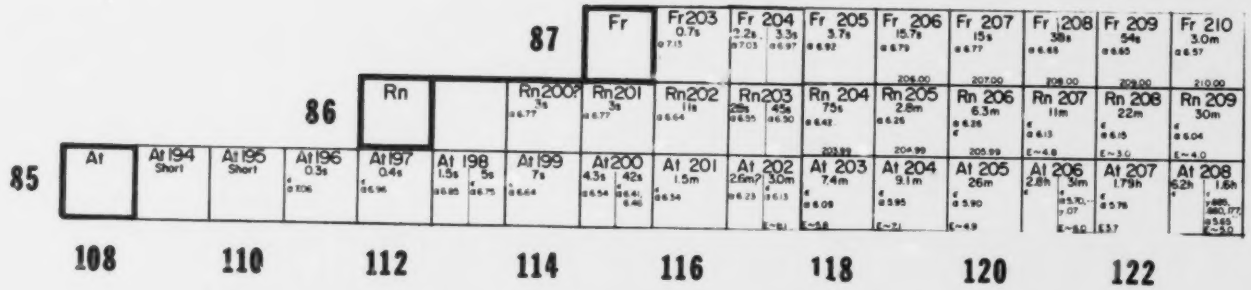
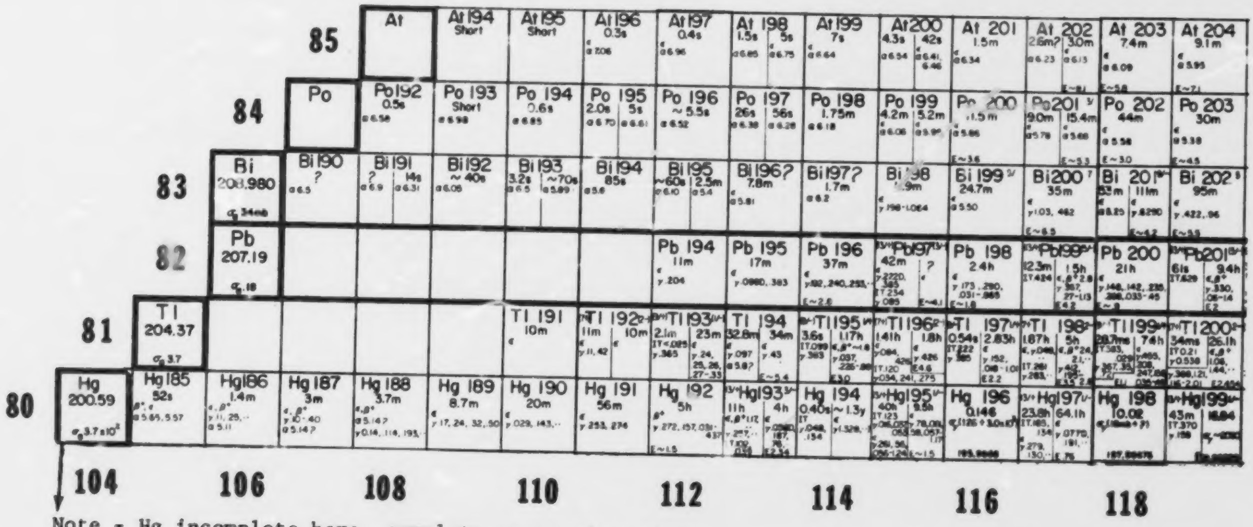
124
126


Hf 168
Hf 169
Hf 170
Hf 171
Hf 172
Hf 173
Hf 175
Hf 176
Hf 177
Hf 178
Hf 179
Hf 180
Hf 181
Hf 182
Hf 183
Lu 167
Lu 168
Lu 169
Lu 170
Lu 171
Lu 172
Lu 173
Lu 174
Lu 175
Lu 177
Lu 178
Lu 179
Lu 180
Yb 166
Yb 167
Yb 168
Yb 169
Yb 170
Yb 171
Yb 172
Yb 173
Yb 174
Yb 175
Yb 176
Yb 177
Tm 165
Tm 166
Tm 167
Tm 168
Tm 169
Tm 170
Tm 171
Tm 172
Tm 173
Tm 174
Tm 175
Tm 176
Er 164
Er 165
Er 166
Er 167
Er 168
Er 169
Er 170
Er 171
Er 172
Er 173
Ho 163
Ho 164
Ho 165
Ho 166
Ho 167
Ho 168
Ho 169
Ho 170
Dy 162
Dy 163
Dy 164
Dy 165
Dy 166
Dy 167
Tb 161
Tb 162
Tb 163
Tb 164
Gd 160
Gd 161
Gd 162
112
110
108
106
104
102
96
98
100


90
89
88
87
Th 232.038
Th213 15s
Th214 13s
Th215 1.2s
Th216 28ms
Th217 <5ms
Ac
Ac209 0.1s
Ac210 ~0.35s
Ac211 ~0.25s
Ac212 ~0.93s
Ac213 0.8s
Ac214 8.2s
Ac215 0.17s
Ac216
Ra
Ra206 0.4s
Ra207 1.3s
Ra208 1.2s
Ra209 4.7s
Ra210 3.8s
Ra211 15s
Ra212 13s
Ra213 2.7m
Ra214 2.6s
Ra215 1.56ms
Ra216 <1ms
Fr
Fr203 0.7s
Fr 204 2.2s 3.3s
Fr 205 3.7s
Fr 206 15.7s
Fr 207 15s
Fr 208 38s
Fr 209 54s
Fr 210 3.0m
Fr 211 3.08m
Fr 212 19m
Fr 213 34.7s
Fr214 34ms 5.0ms
Fr215 <<1ms
116
118
120
122
124
126
128


87
86
85
Fr
Fr203 0.7s
Fr 204 2.2s 3.3s
Fr 205 3.7s
Fr 206 15.7s
Fr 207 15s
Fr 208 38s
Fr 209 54s
Fr 210 3.0m
Rn
Rn200? 3s
Rn201 3s
Rn202 11s
Rn203 28s 45s
Rn 204 75s
Rn205 2.8m
Rn 206 6.3m
Rn 207 11m
Rn 208 22m
Rn 209 30m
At
At194 Short
At195 Short
At196 0.3s
At197 0.4s
At 198 1.5s 5s
At199 7s
At200 4.3s 42s
At 201 1.5m
At 202 2.6m? 3.0m
At 203 7.4m
At 204 9.1m
At 205 26m
At 206 2.8h 31m
At 207 1.79h
At 208 62h 1.6h
108
110
112
114
116
118
120
122


85
84
83
82
81
80
At
At194 Short
At195 Short
At196 0.3s
At197 0.4s
At 198 1.5s 5s
At199 7s
At200 4.3s 42s
At 201 1.5m
At 202 2.6m? 3.0m
At 203 7.4m
At 204 9.1m
Po
Po192 0.5s
Po 193 Short
Po 194 0.6s
Po 195 2.0s 5s
Po 196 ~5.5s
Po 197 26s 56s
Po 198 1.75m
Po 199 4.2m 5.2m
Po 200 11.5m
Po201 9.0m 15.4m
Po 202 44m
Po 203 30m
Bi 208.980
Bi190 ?
Bi191 ? 14s
Bi192 ~40s
Bi193 3.2s ~70s
Bi194 85s
Bi195 ~60s 2.5m
Bi196? 7.8m
Bi197? 1.7m
Bi198 11.9m
Bi 199 24.7m
Bi200 35m
Bi 201 53m 1.1m
Bi 202 95m
Pb 207.19
Pb 194 11m
Pb 195 17m
Pb 196 37m
Pb197 42m ?
Pb 198 2.4h
Pb199 12.3m 1.5h
Pb 200 21h
Pb201 61s 9.4h
Tl 204.37
Tl 191 10m
Tl 192 11m 10m
Tl193 2.1m 23m
Tl 194 32.8m 34m
Tl195 3.6s 1.17h
Tl196 1.41h 1.8h
Tl 197 0.54s 2.83h
Tl 198 1.87h 5h
Tl199 28.7ms 7.4h
Tl200 34ms 26.1h
Hg 200.59
Hg185 52s
Hg186 1.4m
Hg 187 3m
Hg 188 3.7m
Hg 189 8.7m
Hg 190 20m
Hg 191 56m
Hg 192 5h
Hg193 11h 4h
Hg 194 0.40s ~1.3y
Hg195 40s 9.5h
Hg 196 0.146
Hg197 23.8h 64.1h
Hg 198 10.02
Hg199 43m 16.84
104
106
108
110
112
114
116
118

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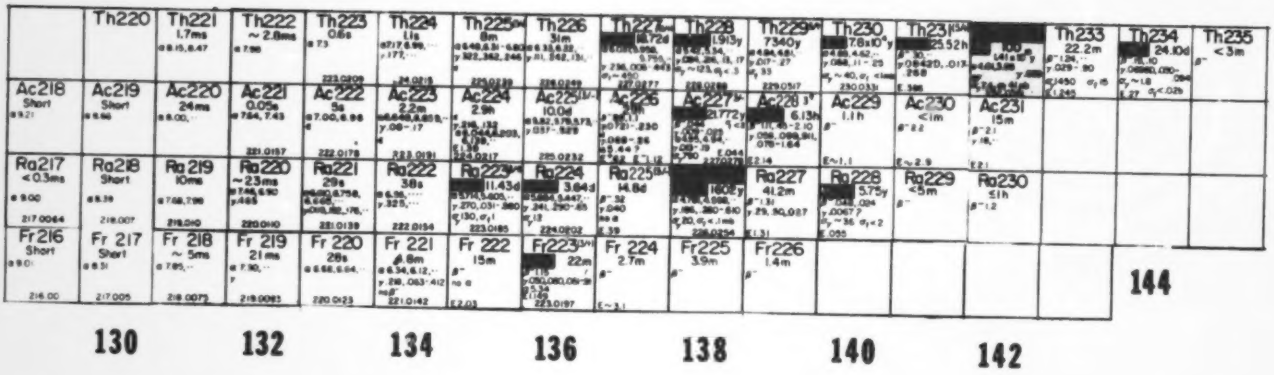
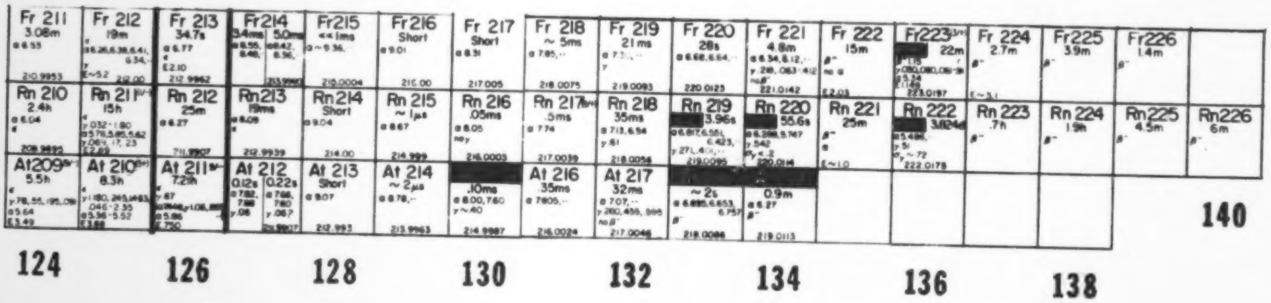
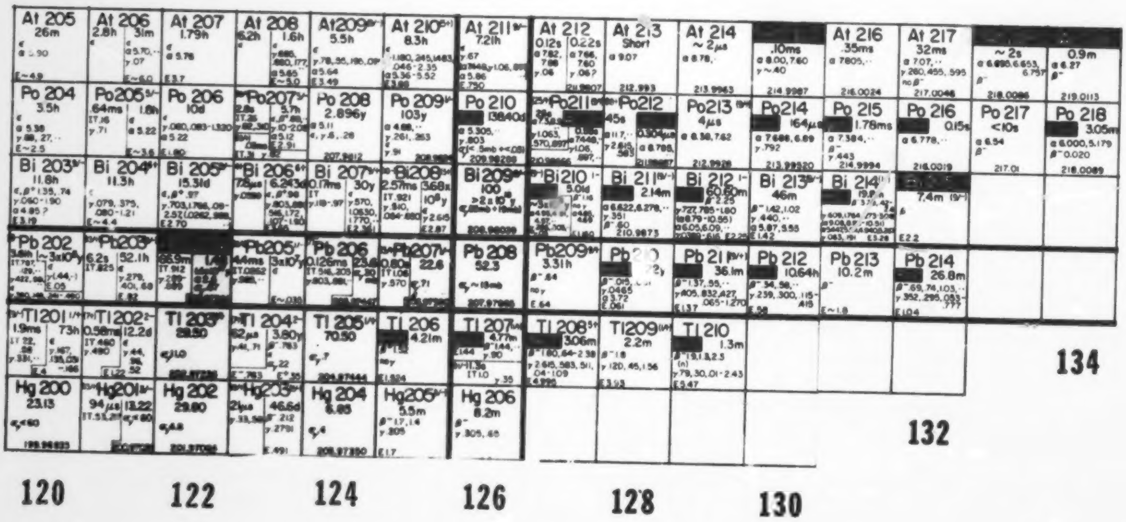
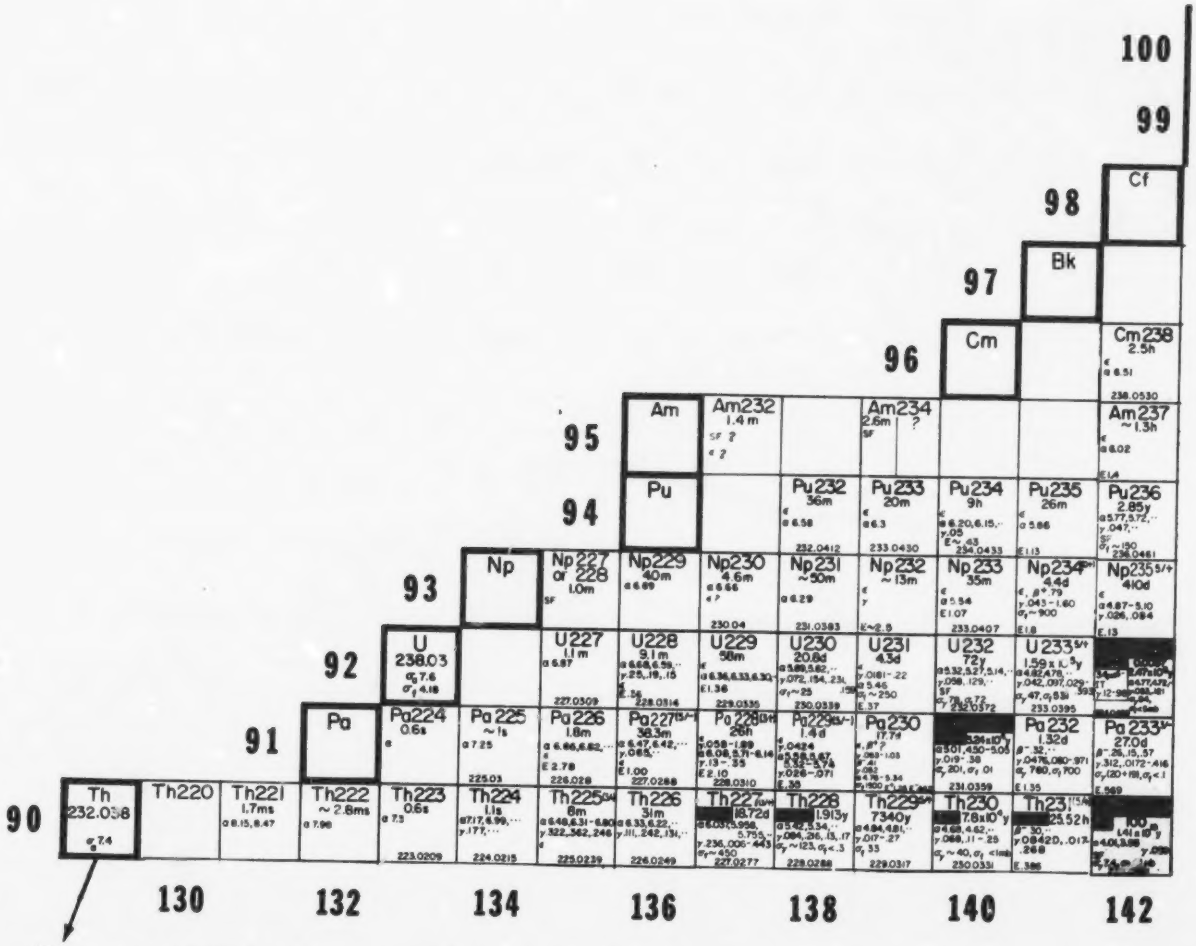

Th220
Th221
Th222
Th223
Th224
Th225
Th226
Th227
Th228
Th229
Th230
Th231
Th233
Th234
Th235
Ac218
Ac219
Ac220
Ac221
Ac222
Ac223
Ac224
Ac225
Ac226
Ac227
Ac228
Ac229
Ac230
Ac231
Ra217
Ra218
Ra219
Ra220
Ra221
Ra222
Ra223
Ra224
Ra225
Ra227
Ra228
Ra229
Ra230
Fr216
Fr 217
Fr 218
Fr 219
Fr 220
Fr 221
Fr 222
Fr223
Fr 224
Fr225
Fr226
144
130
132
134
136
138
140
142


Fr 211
Fr 212
Fr 213
Fr214
Fr215
Fr216
Fr 217
Fr 218
Fr 219
Fr 220
Fr 221
Fr 222
Fr223
Fr 224
Fr225
Fr226
Rn 210
Rn 211
Rn 212
Rn213
Rn214
Rn 215
Rn 216
Rn 217
Rn 218
Rn 219
Rn 220
Rn 221
Rn 222
Rn 223
Rn 224
Rn225
Rn226
At209
At 210
At 211
At 212
At 213
At 214
At 216
At 217
140
124
126
128
130
132
134
136
138


At 205
At 206
At 207
At 208
At209
At 210
At 211
At 212
At 213
At 214
At 216
At 217
Po 204
Po205
Po 206
Po207
Po 208
Po 209
Po 210
Po211
Po212
Po213
Po214
Po 215
Po 216
Po 217
Po 218
Bi 203
Bi 204
Bi 205
Bi 206
Bi 207
Bi208
Bi209
Bi210
Bi 211
Bi 212
Bi 213
Bi 214
Pb 202
Pb203
Pb205
Pb 206
Pb207
Pb 208
Pb209
Pb210
Pb 211
Pb 212
Pb 213
Pb 214
Tl201
Tl202
Tl 203
Tl 204
Tl 205
Tl 206
Tl 207
Tl 208
Tl209
Tl 210
Hg 200
Hg201
Hg 202
Hg203
Hg 204
Hg205
Hg 206
134
132
120
122
124
126
128
130


100
99
98
Cf
97
Bk
96
Cm
Cm238
2.5h
95
Am
Am232
1.4 m
Am234
2.6m
Am237
~1.3h
94
Pu
Pu232
36m
Pu233
20m
Pu234
9h
Pu235
26m
Pu236
2.85y
93
Np
Np227 or 228
1.0m
Np229
40m
Np230
4.6m
Np231
~50m
Np232
~13m
Np233
35m
Np234
4.4d
Np235
410d
92
U
238.03
U227
1.1 m
U228
9.1 m
U229
58m
U230
20.8d
U231
4.3d
U232
72y
U233
1.59 x 10⁵y
91
Pa
Pa224
0.6s
Pa225
~1s
Pa226
1.8m
Pa227
38.3m
Pa228
26h
Pa229
1.4d
Pa230
17.7d
Pa232
1.32d
Pa233
27.0d
90
Th
232.038
Th220
Th221
1.7ms
Th222
~2.8ms
Th223
0.6s
Th224
1.1s
Th225
8m
Th226
31m
Th227
18.72d
Th228
1.913y
Th229
7340y
Th230
7.8x10⁴y
Th231
25.52h
130
132
134
136
138
140
142

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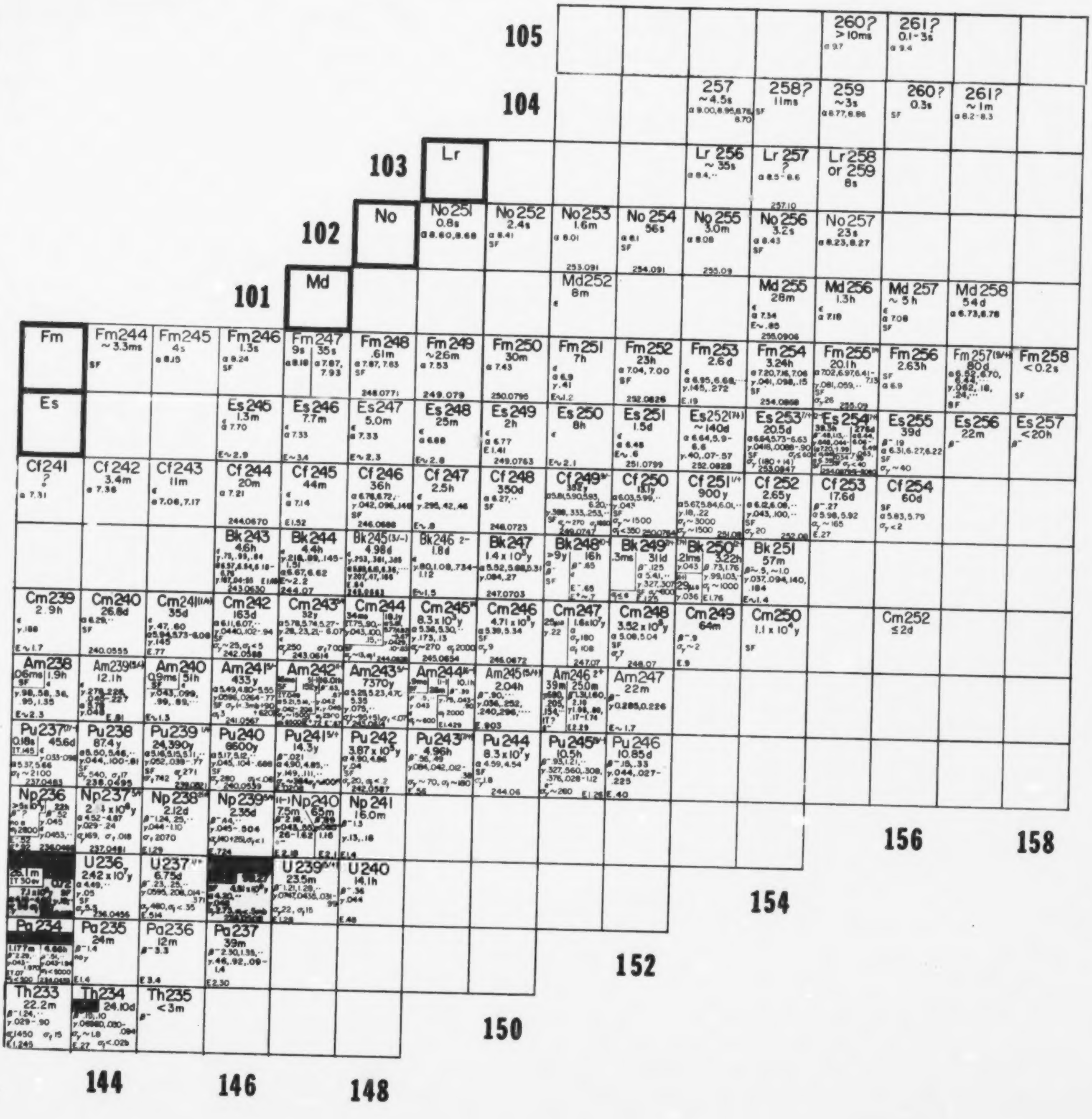
105
104
103
102
101
Lr
No
Md
Fm
Es
260? >10ms
261? 0.1-3s
257 ~4.5s
258? 11ms
259 ~3s
260? 0.3s
261? ~1m
Lr 256 ~35s
Lr 257 ?
Lr 258 or 259 8s
No 251 0.8s
No 252 2.4s
No 253 1.6m
No 254 56s
No 255 3.0m
No 256 3.2s
No 257 23s
Md 252 8m
Md 255 28m
Md 256 1.3h
Md 257 ~5h
Md 258 54d
Fm 244 ~3.3ms
Fm 245 4s
Fm 246 1.3s
Fm 247 9s 35s
Fm 248 .61m
Fm 249 ~2.6m
Fm 250 30m
Fm 251 7h
Fm 252 23h
Fm 253 2.6d
Fm 254 3.24h
Fm 255 20.1h
Fm 256 2.63h
Fm 257 80d
Fm 258 <0.2s
Es 245 1.3m
Es 246 7.7m
Es 247 5.0m
Es 248 25m
Es 249 2h
Es 250 8h
Es 251 1.5d
Es 252 ~140d
Es 253 20.5d
Es 254
Es 255 39d
Es 256 22m
Es 257 <20h
Cf 241 ?
Cf 242 3.4m
Cf 243 11m
Cf 244 20m
Cf 245 44m
Cf 246 36h
Cf 247 2.5h
Cf 248 350d
Cf 249
Cf 250
Cf 251 900y
Cf 252 2.65y
Cf 253 17.6d
Cf 254 60d
Bk 243 4.6h
Bk 244 4.4h
Bk 245 4.98d
Bk 246 1.8d
Bk 247 1.4 x 10³y
Bk 248 >9y 16h
Bk 249 311d
Bk 250 3.22h
Bk 251 57m
Cm 239 2.9h
Cm 240 26.8d
Cm 241 35d
Cm 242 163d
Cm 243 32y
Cm 244
Cm 245 8.3 x 10³y
Cm 246 4.71 x 10³y
Cm 247
Cm 248 3.52 x 10⁵y
Cm 249 64m
Cm 250 1.1 x 10⁴y
Cm 252 ≤2d
Am 238 1.9h
Am 239 12.1h
Am 240 51h
Am 241 433y
Am 242
Am 243 7370y
Am 244 10.1h
Am 245 2.04h
Am 246 25.0m
Am 247 22m
Pu 237 45.6d
Pu 238 87.4y
Pu 239 24,390y
Pu 240 6600y
Pu 241 14.3y
Pu 242 3.87 x 10⁵y
Pu 243 4.96h
Pu 244 8.3 x 10⁷y
Pu 245 10.5h
Pu 246 10.85d
Np 236
Np 237 2.14 x 10⁶y
Np 238 2.12d
Np 239 2.35d
Np 240 7.5m 65m
Np 241 16.0m
U 236 2.42 x 10⁷y
U 237 6.75d
U 239 23.5m
U 240 14.1h
Pa 234
Pa 235 24m
Pa 236 12m
Pa 237 39m
Th 233 22.2m
Th 234 24.10d
Th 235 <3m
144
146
148
150
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SECTION II
RADIOISOTOPE, DECAY, AND RADIOASSAY DATA

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COMMONLY AVAILABLE RADIONUCLIDES LISTED ALPHABETICALLY

Radionuclide	Half-Life*	Radiation†
Americium-241	458y	α, e^-, γ
Antimony-122	67h	β^-, β^+, γ
Antimony-124	60d	β^-, γ
Antimony-125	2.7y	β^-, e^-, γ
Argon-37	35d	γ
Arsenic-74	17.9d	β^-, β^+, γ
Arsenic-76	26.5h	β^-, γ
Arsenic-77	38.7h	β^-, γ
Barium-131	12d	γ, e^-
Barium-133	7.2y	γ, e^+
Barium-137m	2.55m	γ, e^-
Barium-140	12.8d	β^-, e^-, γ
Beryllium-7	53d	γ
Bismuth-207	30y	e^-, γ
Bismuth-210	5.01d	α, β^-, γ
Bromine-82	35.34h	β^-, γ
Cadmium-109	453d	e^-, γ
Cadmium-115	53.5h	β^-, γ
Cadmium-115m	43d	β^-, γ
Calcium-45	165d	β^-
Calcium-47	4.53d	β^-, γ
Carbon-14	5730y	β^-
Cerium-141	33d	β^-, e^-, γ
Cerium-144	284d	β^-, e^-, γ
Cesium-131	9.70d	γ
Cesium-134	2.05y	β^-, γ
Cesium-137	30.0y	β^-, e^-, γ
Chlorine-36	3.1×10^5 y	β^-, γ
Chromium-51	27.8d	e^-, γ
Cobalt-57	270d	e^-, γ
Cobalt-58	71.3d	β^+, γ
Cobalt-60	5.26y	β^-, γ
Copper-64	12.8h	$\beta^-, e^-, \beta^+, \gamma$
Dysprosium-159	144d	e^-, γ
Erbium-169	9.4d	β, e^-, γ
Europium-152	12y	$\beta^-, \beta^+, e^-, \gamma$
Europium-154	16y	β^-, e^-, γ
Europium-155	1.81y	β^-, e^-, γ
Gadolinium-153	242d	e^-, γ
Gallium-68	68.3m	β^+, γ
Gallium-72	14.1h	β^-, γ
Germanium-71	11.4d	γ
Gold-195	183d	e^-, γ
Gold-198	64.8h	β^-, e^-, γ
Gold-199	75.6h	β^-, e^-, γ
Hafnium-181	42.5d	β^-, e^-, γ
Holmium-166	26.9h	β^-, e^-, γ
Hydrogen-3	12.3y	β^-
Indium-113m	100m	e^-, γ
Indium-114	72s	β^-, β^+, γ
Indium-114m	50.0d	e^-, γ (D.R.)
Iodine-125	60d	e^-, γ
Iodine-129	1.7×10^7 y	β^-, e^-, γ
iodine-130	12.4h	β^-, γ
Iodine-131	8.05d	$\beta^-. e^-, \gamma$
Iridium-192	74.2d	β^-, e^-, γ
Iridium-194	17.4h	$\beta x, \gamma$
Iron-55	2.6y	γ
Iron-59	45d	β^-, γ
Krypton-85	10.76y	β^-, γ
Lanthanum-140	40.22h	β^-, γ
Lead-210	21y	$\alpha, \beta^-, e^-, \gamma$
Lutetium-177	6.7d	β^-, e^-, γ
Magnesium-28	21h	β^-, e^-, γ
Manganese-54	303d	e^-, γ
Mercury-197	65h	e^-, γ
Mercury-197m	24h	e^-, γ
Mercury-203	46.9d	β^-, e^-, γ

COMMONLY AVAILABLE RADIONUCLIDES LISTED ALPHABETICALLY--Continued

Radionuclide	Half-Life*	Radiation†
Molybdenum-99	67h	β^-,γ
Neodymium-147	11.1d	β^-,e^-,γ
Nickel-63	92y	β^-
Niobium-95	35d	β^-,γ
Osmium-191	15d	β^-,e^-,γ
Palladium-103	17d	γ
Palladium-109	13.47h	β^-,e^-,γ
Phosphrous-32	14.3d	β^-
Polonium-210	138,4d	α,γ
Potassium-42	12.4h	β^-,γ
Praseodymium-142	19.2h	β^-,γ
Praseodymium-143	13.6d	β^-
Praseodymium-144	17.3m	β^-,γ
Promethium-147	2.62y	β^-
Protactinium-233	27.0d	β^-,e^-,γ
Protactinium-234	6.75h	β^-,e^-,γ
Radium-226	1602y	α,e^-,γ (D.R.)
Rhenium-186	90h	β^-,e^-,γ
Rhodium-106	30s	β^-,γ
Rubidium-86	18.66d	β^-,γ
Ruthenium-97	2.9d	e^-,γ
Ruthenium-103	39.6d	β^-,γ
Ruthenium-106	367d	β^- (D.R.)
Samarium-151	87y	β^-,e^-,γ
Samarium-153	47h	β^-,e^-,γ
Scandium-46	83.9d	β^-,γ
Selenium-75	120.4d	e^-,γ
Silver-110	24.4s	β^-,γ
Silver-110m	253d	β^-,e^-,γ
Silver-111	7.5d	β^-,γ
Sodium-22	2.60y	β^+,γ
Sodium-24	15.0h	β^-,γ
Strontium-85	64d	e^-,γ
Strontium-87m	2.83h	e^-,γ
Strontium-89	52d	β^-,γ
Strontium-90	28.1y	β^- (D.R.)
Sulfur-35	88d	β^-
Tantalum-132	115d	β^-,e^-,γ
Technetium-99	2.12×10^5 y	β^-
Technetium-99m	6.0h	e^-,γ
Tellurium-132	78h	β^-,e^-,γ
Terbium-160	72.1d	β^-,e^-,γ
Thallium-204	3.8y	β^-,γ
Thulium-170	130d	β^-,e^-,γ
Tin-113	115d	γ
Tin-119m	250d	e^-,γ
Titanium-44	48h	e^-,γ (D.R.)
Tungsten-185	75d	β^-
Tungsten-187	23.9h	β^-,e^-,γ
Uranium-238	4.51×10^9 y	α,e^-,γ (D.R.)
Xenon-133	5.27d	β^-,e^-,γ
Ytterbium-169	32d	e^-,γ
Yttrium-90	64h	β^-,γ
Yttrium-91	58.8d	β^-,γ
Zinc-65	245d	β^+,e^-,γ
Zinc-69	57m	β^-
Zirconium-95	65d	β^-,γ (D.R.)

---

*s = second, m = minute, h = hour, d = day, y = year, D.R. = daughter radiation.

†Conversion electrons (e-) are listed if they are prominent in the electron spectrum. Decay products may give rise to other types of radiation. This is indicated, where prominent, by the notation (D.R.).

Source: Half-lives and radiation are taken from The Table of Isotopes, by C. M. Lederer, J. M. Hollander, and I. Perlman (6th ed.; New York: John Wiley & Sons, Inc., 1967).

ALPHA EMITTERS BY INCREASING ENERGY

MeV	Source	Half-life	Yield* (%)
1.83	Nd-144	2.4×10^{15} y	100
2.14	Gd-152	1.1×10^{14} y	100
2.23	Sm-147	1.05×10^{11} y	100
2.46	Sm-146	7×10^{7} y	100
2.50	Hf-174	2×10^{15} y	100
2.73	Gd-150	2.1×10^{6} y	100
3.18	Gd-148	84y	100
3.18	Pt-190	6×10^{11} y	100
3.95	Th-232	1.41×10^{10} y	23
4.011	Th-232	1.41×10^{10} y	77
4.15	U -238	4.51×10^{9}	23
4.200	U -238	4.51×10^{9} y	77
4.366	U -235	7.1×10^{8} y	18
4.396	U -235	7.1×10^{8} y	57
4.415	U - 35	7.1×10^{8} y	4
4.44	U -236	2.39×10^{7} y	26
4.493	U -236	2.39×10^{7} y	74
4.556	U -235	7.1×10^{8} y	4
4.57	Bi-210m	3×10 y	6
4.597	U -235	7.1×10^{8} y	5
4.599	Ra-226	1602y	6
4.617	Th-230	8.0×10^{4} y	24
4.684	Th-230	8.0×10^{4} y	76
4.722	U -234	2.47×10^{5} y	28
4.733	Pa-231	3.25×10^{4} y	11
4.765	Np-237	2.14×10^{6} y	17
4.770	Np-237	2.14×10^{6} y	19
4.773	U -234	2.47×10^{5} y	72
4.778	U -233	1.62×10^{5} y	15
4.782	Ra-226	1602y	95
4.787	Np-237	2.14×10^{6} y	51
4.811	Th-229	7340y	11
4.821	U -233	1.62×10^{5} y	83
4.842	Th-229	7340y	58
4.863	Pu-242	3.79×10^{5} y	24
4.896	Pu-241	13.2y	0.002
4.899	Th-229	7340y	11
4.903	Pu-242	3.79×10^{5} y	76
4.92	Bi-210m	3×10^{6} y	36
4.95	Ac-227	21.6y	1.2
4.951	Pa-231	3.25×10^{4} y	22
4.96	Bi-210m	3×10^{6} y	58
4.967	Th-229	7340y	6
5.013	Pa-231	3.25×10^{4} y	24
5.028	Pa-231	3.25×10^{4} y	23
5.054	Th-229	7340y	7
5.058	Pa-231	3.25×10^{4} y	11
5.105	Pu-239	24,400y	12
5.123	Pu-240	6580y	24
5.143	Pu-239	24,400y	15
5.156	Pu-239	24,400y	73
5.168	Pu-240	6580y	76
5.234	Am-243	7.95×10^{3} y	11
5.267	U -232	72y	32
5.276	Am-243	7.95×10^{3} y	88
5.305	Po-210	138.4d	100
5.306	Cm-245	9.3×10^{3} y	7
5.324	U -232	72y	68
5.342	Cm-246	5.5×10^{3} y	19
5.344	h-228	1.910y	28
5.362	Cm-245	9.3×10^{3} y	80
5.386	Cm-246	5.5×10^{3} y	81
5.42	Bk-249	314d	0.0015
5.427	Th-228	1.910y	71
5.443	Am-241	458y	13
5.447	Ra-224	3.64d	6
5.448	Bi-214	19.7m	0.012
5.456	Pu-238	86y	28
5.486	Am-241	458y	86
5.490	Rn-222	3.823d	100
5.499	Pu-238	86y	72
5.512	Bi-214	19.7m	0.008
5.52	Bk-247	1.4×10^{3} y	58
5.537	Ra-223	11.43d	9
5.605	Ra-223	11.43d	26
5.666	Cf-251	800y	55
5.68	Bk-247	1.4×10^{3} y	37
5.684	Ra-224	3.64d	94
5.707	Th-227	18.2d	8
5.714	Ra-223	11.43d	54
5.73	Ac-225	10.0d	10
5.742	Cm-243	32y	12
5.745	Ra-223	11.43d	9
5.755	Th-227	18.2d	20
5.763	Cm-244	17.6y	23
5.786	Cm-243	32y	73
5.79	Ac-225	10.0d	28
5.806	Cm-244	17.6y	77
5.812	Cf-249	360y	84
5.816	U -230	20.8d	32
5.83	Ac-225	10.0d	54
5.846	Cf-251	800y	45
5.868	At-211	7.21h	41
5.87	Bi-213	47m	2
5.887	U -230	20.8d	68
5.976	Th-227	18.2d	23
5.987	Cf-250	13y	17
5.994	Cm-243	32y	6
6.002	Po-218	3.05m	100
6.031	Cf-250	13y	83
6.037	Th-227	18.2d	24
6.051	Bi-212	60.6m	25

ALPHA EMITTERS BY INCREASING ENERGY--Continued

MeV	Source	Half-life	Yield* (%)	MeV	Source	Half-life	Yield* (%)
6.061	Cm-243	32y	6	6.640	Es-253	20.47d	90
6.071	Cm-242	163d	26	6.65	At-218	2s	6
6.076	Cf-252	2.65y	15	6.70	At-218	2s	94
6.090	Bi-212	60.6m	10	6.777	Po-216	0.15s	100
6.115	Cm-242	163d	74	6.818	Rn-219	4.0s	81
6.119	Cf-252	2.65y	84	7.027	Fm-255	20.1h	93
6.126	Fr-221	4.8m	15	7.07	At-217	32ms	100
6.22	Th-226	30.9m	19	7.14	Rn-218	35ms	100
6.278	Bi-211	2.15m	16	7.158	Fm-254	3.24h	14
6.28	At-219	0.9m	97	7.200	Fm-254	3.24h	85
6.287	Rn-220	55s	100	7.28	Po-211m	25s	91
6.34	Th-226	30.9m	79	7.384	Po-215	1.78ms	100
6.340	Fr-221	4.8m	82	7.448	Po-211	0.52s	99
6.424	Rn-219	4.0s	8	7.687	Po-214	164μs	100
6.437	Es-254	276d	93	8.377	Po-213	4.2μs	100
6.551	Rn-219	4.0s	11	8.785	Po-212	0.30μs	100
6.56	Ra-222	38s	96	8.88	Po-211m	25s	7
6.622	Bi-211	2.15m	84	11.65	Po-212m	45s	97

*Percentage of the total decay events.

This table can help identify unknown beta emitters whose half-life and energy have been determined by standard laboratory techniques. A detailed compilation of nuclear data, such as National Bureau of Standards Circular 449 and supplements, should be consulted for details of these emitters and their decay.

Emitters of conversion electrons and positrons as well as emitters of beta rays are included, since all these particles produce similar effects when absorption methods are used to determine energy. Whereas isotopes can decay by emission of beta particles of different energies, the emitter is listed in the energy group corresponding to each beta, provided its contribution to total beta activity is greater than 5%. All the betas from one emitter will lie in the same half-life interval. Isomers and metastable states of nuclides are included, but these properties are not indicated here.

Only isotopes with half-lives greater than six hours are listed; in general, a shorter half-life limits identification by the methods described.

Daughters with shorter half-lives than their parents are listed in italics under the half-life of the parent. In the natural series, the short-lived daughters are listed under the half-life of the nearest antecedent having a half-life over six hours.

BETA EMITTERS BY ENERGY AND HALF-LIFE*

Half-Life	E_{max} (Mev) 0-0.1	0.1-0.3	0.3-0.5	0.5-0.7
0-12 hr.	Zn^{62}	Tm^{166} Bi^{204} Pa^{234}	I^{135} Tl^{198} Pb^{212} Ac^{228} Pa^{234}	Zn^{62} Sr^{91} Pd^{101} Ta^{180} Pb^{212} Ac^{228} Pa^{234}
12 hr-1 d		Nb^{90} Pd^{112} Au^{193}	Y^{87} Nb^{96} I^{133} Ir^{194}	Cu^{64} Ga^{72} Br^{76} I^{130} Pr^{142} Gd^{159} Pt^{197} Np^{236} Am^{242}
1-3 d	Ho^{166} Lu^{170} Ta^{177} Th^{231}	As^{71} Zn^{72} Ba^{135} Ce^{143} Sm^{153} Tb^{153} Th^{231} Pa^{232} Np^{238}	Cu^{67} Br^{77} Br^{82} Mo^{99} In^{115} Sn^{121} Te^{131} W^{187} Tl^{200} Pa^{232} Np^{238}	Sc^{48} Cu^{67} Ge^{69} Ga^{72} As^{7-} As^{77} Rh^{105} Cd^{115} Te^{131} Ce^{143} Sm^{153} W^{187} Os^{193} Np^{239}
3-5 d	Ho^{166} Yb^{175}	Te^{132} Dy^{166} Yb^{175} Re^{186} Pt^{193} Au^{199}	Sc^{47} Yb^{175} Au^{199} Bi^{214}	Sc^{47} Ca^{47} Y^{87} I^{124} Ta^{183} Pb^{214}
5-10 d	Xe^{133} Tb^{155}	Cs^{131} Tm^{167} Lu^{171} Lu^{172} Lu^{177} U^{237}	Sn^{125} I^{131} Xe^{133} Tb^{161} Er^{169} Lu^{177}	Mn^{52} As^{72} Ag^{111} I^{131} Cs^{132} Tb^{161} Pb^{209}
10-13 d	Nd^{147} Ir^{190}	Ba^{131} Nd^{147}	I^{126} Cs^{136} Ba^{140} Nd^{147} Pb^{211}	Cs^{136}
13-15 d			Ra^{225}	
15-20 d		Os^{191}	Eu^{156} Pa^{230}	V^{48} As^{74}
20-30 d		Pa^{233} Th^{234} Pa^{234}	Pa^{233} Pa^{234}	Pa^{234}
30-40 d	Rh^{103}	Nb^{95} Ru^{103} Te^{129}	Ce^{141}	Ce^{141}
40-50 d		Fe^{59} Hg^{203}	Fe^{59} Hf^{181}	
50-100 d		S^{35} Nb^{95} Sb^{124} Tm^{168}	Sc^{46} Co^{58} Zr^{95} Tb^{160} Tm^{168} W^{185}	Sb^{124} Tb^{160} Ir^{192}
100-150 d	Gd^{151}	W^{181}	Ta^{182}	Ta^{182}
150-200 d		Ca^{45} Lu^{174}		Lu^{174}
200-250 d			Zn^{65}	
250 d-1 y	Ru^{106} Ag^{110}	Ce^{144}	Co^{57} Ce^{144}	Ag^{110}
1-2 y	Tm^{171}	Eu^{155}	Sn^{121}	
2-3 y	Cs^{134}	Sb^{125} Pm^{147}		Na^{22} Sb^{125} Cs^{134}
3-5 y		Lu^{172}		
5-10 y	Ra^{228}		Co^{60} Ac^{228}	Cd^{113} Ac^{228}
10-20 y	H^{3} Pb^{210} Pu^{241}	Eu^{152} Eu^{154} U^{237}	Eu^{152}	Kr^{85} Eu^{152} Eu^{154}
20-30 y	Ac^{227}			Sr^{90} Cs^{137}
30-50 y				
50-100 y	Sm^{151}			
> 100 y	Ni^{63} Pd^{107} Re^{187} Ac^{227} Ra^{228} Th^{231}	C^{14} Rb^{87} Tc^{99} I^{129} Cs^{135} Th^{231} Pa^{233} Th^{234} Np^{239}		Be^{10} In^{115} Am^{242}

BETA EMITTERS BY ENERGY AND HALF-LIFE*

0.7-0.9	0.9-1.1	1.1-1.3	1.3-1.5	1.5-1.7	1.7-1.9	1.9-2.1	2.1-2.3	2.3-2.5	2.5-2.7	2.7-2.9	2.9-3.1	3.1-3.5	3.5-3.7	3.7-3.9	3.9-4.2
Fe^{52} Ga^{66} Se^{73} Ge^{77} Rb^{82} Te^{127} Sm^{156} Ta^{180}	Sr^{91} I^{135} Xe^{135} Er^{171}	Ac^{228} Pa^{234}	Se^{73} Ge^{77} Sr^{91} I^{135} Er^{171}	Ac^{228}	Eu^{152} *Tl*^{208} Ac^{228}	Tm^{166}	Ge^{77} Pd^{101} *Bi*^{212} Ac^{228}		*Mn*^{52} Sr^{91}	Y^{93}	*Cu*^{62}				Ga^{66}
K^{43} Zn^{69} Br^{76} Nb^{96} Ce^{135}	Co^{55} Ga^{72} Pd^{109} *Ag*^{112} I^{130} Eu^{157} Gd^{159} Ir^{194}	Br^{76} *Nb*^{97} Rh^{100}	Na^{24} Co^{55} I^{133}	Ga^{72} Nb^{96} Tb^{154} Eu^{157}	Br^{76}	K^{42} Zr^{97} Rh^{100} Re^{188} Ir^{194}	Pr^{142} Re^{188} Ir^{194}		Ga^{72} Rh^{100}	*Ag*^{112} Tb^{154}		Ga^{72}	K^{42} Br^{76} *Ag*^{112}		*Ag*^{112}
Ni^{57} As^{71} *In*^{115} La^{140} Sm^{153} Ho^{166} Os^{193} Np^{239}	*Ga*^{72} Pm^{149} Pm^{151} Os^{193} Au^{198} Tl^{200}	Ge^{69} Mo^{99} Cd^{115} La^{140} Ce^{143} Os^{193} Pa^{232} Np^{238}	*Sc*^{44} Sb^{122} La^{140} Ce^{143} W^{187} Tl^{200}	*Cu*^{66} *Ga*^{72} Zn^{72} Te^{131} La^{140}	As^{72} As^{76} Ho^{166}	Sb^{122}	Y^{90} Te^{131} La^{140}	*As*^{76}	*Cu*^{66} *Ga*^{72} As^{72}		As^{76}	*Ga*^{72} As^{72}			
Te^{127} Sb^{127} *I*^{132} *Ho*^{166} *Pb*^{214}	Zr^{89} Re^{186} *Bi*^{214}	*Rh*^{100} Sb^{127} *I*^{132}	I^{128}	Sb^{127} *I*^{132} *Bi*^{214}	*Ho*^{166} *Bi*^{214}	Ca^{87} *Rh*^{100}	I^{128} *I*^{132} *Pr*^{140} *Bi*^{212}		*Rh*^{100}			*Bi*^{214}			
Sb^{118}	Ag^{111} *Bi*^{213}	Bi^{210}	*Bi*^{213}		*As*^{72}			Sn^{125} Pm^{148}	As^{72}		*Sb*^{118}	*As*^{72}			
I^{126} *La*^{140} Nd^{147}	Nb^{92} Ba^{140}	I^{126} La^{140}	*La*^{140} *Tl*^{207} *Pb*^{211}	*La*^{140}			*La*^{140}								
	Pr^{143}				P^{32}										
Rb^{86}	As^{74}		As^{74}	As^{74}	Rb^{86}			Eu^{156}							
	Ta^{178}	*Pa*^{234}						*Pa*^{234}							
Rb^{84}	Rb^{84} *Te*^{129}		*Te*^{129}	Rb^{84}											
				Cd^{115}		*In*^{114}									
Tb^{160}	Sb^{124}		Co^{56} Sr^{89}	Y^{91} Sb^{124}				Sb^{124}							
Te^{127} Tm^{170}	Tm^{170}		Sn^{123}												
Rh^{102}		Rh^{102}													
Rh^{106}					*Ga*^{68}			*Rh*^{106}			*Pr*^{144}	*Rh*^{106}	*Rh*^{106}		
							Bi^{212}								
Tl^{204}															
		Ac^{228}		*Ac*^{228}	*Ac*^{228}		*Bi*^{212} *Ac*^{228}								
Eu^{154}	Eu^{152}	*Bi*^{210}	Eu^{152}		Eu^{154}										
		Cs^{137} *Fr*^{223}					*Y*^{90}								
Cl^{36}		Al^{26} Np^{238}	K^{40} *Sc*^{44}				*Bi*^{212}								

* This chart is a revision of the original table by Naomi A. Hallden, Physicist, Analytical Branch, U.S.A.E.C.

AVERAGE AND MAXIMUM BETA ENERGY BY RADIONUCLIDE

Nuclide	Energy in MeV		Nuclide	Energy in MeV		Nuclide	Energy in MeV	
	(av)	(max)		(av)	(max)		(av)	(max)
n - 1	0.301	---	Mn- 57	1.099	2.600	Rb- 87	0.079	0.274
H - 3	0.005	0.018	Fe- 59	0.116	1.560	Kr- 88	0.367	2.600
He- 6	1.571	3.515	Fe- 60	0.069	0.240	Rb- 88	2.084	5.177
Be- 10	0.229	0.555	Co- 60	0.094	1.478	Kr- 89	1.395	3.920
C - 14	0.049	0.158	Co- 60A	0.604	1.545	Rb- 89	0.596	3.920
C - 15	2.871	9.775	Fe- 61	1.193	2.800	Sr- 89	0.583	1.470
O - 19	1.708	4.601	Co- 61	0.463	1.231	Sr- 90	0.200	0.544
O - 20	1.242	2.850	Co- 62	0.983	2.831	Y - 90	0.931	2.245
F - 20	2.486	5.403	Co- 63	1.577	3.600	Kr- 91	1.561	3.600
F - 21	2.624	5.683	Ni- 63	0.017	0.066	Rb- 91	1.849	4.200
Ne- 23	1.903	4.372	Cu- 64	0.188	0.573	Rb- 91A	1.271	3.000
Ne- 24	0.794	1.980	Ni- 65	0.667	2.100	Sr- 91	0.624	2.665
Na- 24	0.553	4.170	Ni- 66	0.064	0.224	Y - 91	0.615	1.548
Na- 25	1.510	3.801	Cu- 66	1.062	2.630	Sr- 92	0.213	1.500
Na- 26	3.124	6.700	Cu- 67	0.146	0.577	Y - 92	1.454	3.600
Mg- 27	0.689	1.763	Cu- 68	1.284	3.000	Y - 93	1.185	2.890
Mg- 28	0.155	0.457	Zn- 69	0.324	0.913	Zr- 93	0.015	0.063
Al- 28	1.244	2.868	Ga- 70	0.644	1.650	Y - 94	2.368	5.320
Al- 29	1.034	2.500	Zn- 71	0.921	2.240	Nb- 94	0.156	0.500
Al- 30	2.307	5.050	Zn- 71A	0.580	1.500	Nb- 94A	0.480	1.300
Si- 31	0.588	1.476	Zn- 72	0.116	1.600	Zr- 95	0.115	1.130
Si- 32	0.028	0.100	Ga- 72	0.429	3.166	Nb- 95	0.046	0.930
P - 32	0.694	1.709	Ga- 73	0.433	1.480	Y - 96	1.507	3.500
P - 33	0.076	0.248	Ga- 74	1.021	4.300	Nb- 96	0.244	0.707
P - 34	2.075	5.100	As- 74	0.405	1.355	Zr- 97	0.713	1.910
S - 35	0.048	0.167	Ga- 75	1.425	3.300	Nb- 97	0.464	1.267
Cl- 36	0.252	0.714	Ge- 75	0.404	1.137	Tc- 98	0.086	0.300
S - 37	0.795	4.750	Ga- 76	2.741	6.000	Nb- 99	1.359	3.200
S - 38	0.463	3.000	As- 76	1.085	2.970	Mo- 99	0.398	1.215
Cl- 38	1.515	4.924	Ge- 77	0.637	2.270	Tc- 99	0.085	0.295
Cl- 39	0.847	3.450	Ge- 77A	1.198	2.880	Nb-100A	1.450	4.200
Ar- 39	0.219	0.565	As- 77	0.221	0.684	Mo-101	0.419	2.230
K - 40	0.541	1.322	Ge- 78	0.317	0.900	Tc-101	0.478	1.320
Ar- 41	0.479	2.515	As- 78	1.471	4.270	Mo-102	0.436	1.200
K - 42	1.446	3.559	As- 79	0.945	2.300	Tc-102	1.835	4.200
K - 43	0.301	1.838	Se- 79	0.058	0.158	Tc-102A	0.792	2.000
Ca- 45	0.076	0.254	Br- 80	0.748	2.000	Rh-102	0.144	0.470
Sc- 46	0.112	1.465	As- 81	1.663	3.800	Tc-103	1.025	2.500
Ca- 47	0.341	2.000	Se- 81	0.531	1.400	Ru-103	0.062	0.710
Sc- 47	0.160	0.601	Br- 82	0.137	0.444	Tc-104	0.978	2.400
Sc- 48	0.220	0.643	Se- 83A	1.379	3.400	Rh-104	0.988	2.441
Ca- 49	0.758	1.984	Br- 83	0.335	0.960	Rh-104A	0.451	1.240
Sc- 49	0.826	2.011	Br- 84	1.221	4.680	Ru-105	0.415	1.870
Sc- 50	1.538	3.500	Br- 84A	0.709	3.200	Rh-105	0.167	0.563
Ti- 51	0.870	2.142	Rb- 84	0.582	1.648	Ru-106	0.009	0.039
V - 52	1.069	2.532	Br- 85	1.037	2.500	Rh-106	1.415	3.541
V - 53	1.068	2.530	Kr- 85	0.249	0.672	Rh-106A	0.345	1.620
V - 54	1.438	3.300	Kr- 85A	0.284	0.826	Ru-107	1.637	4.008
Cr- 55	1.220	2.850	Rb- 86	0.622	1.777	Rh-107	0.425	1.201
Cr- 56	0.587	1.500	Br- 87	1.872	8.000	Pd-107	0.013	0.035
Mn- 56	0.860	2.850	Kr- 87	1.334	3.800	Ru-108	0.466	1.320

A = First excited state.

AVERAGE AND MAXIMUM BETA ENERGY BY RADIONUCLIDE--Continued

Nuclide	Energy in MeV		Nuclide	Energy in MeV		Nuclide	Energy in MeV	
	(av)	(max)		(av)	(max)		(av)	(max)
Rh-108	1.821	4.500	I -126	0.298	1.250	Pr-146	1.292	3.780
Ag-108	0.624	1.650	Sb-127	0.375	1.500	Pm-146	0.233	0.725
Pd-109	0.359	1.025	Te-127	0.223	0.695	Nd-147	0.227	0.810
Ag-110	1.176	2.869	Te-127A	0.263	0.730	Pm-147	0.062	0.225
Ag-110A	0.070	0.530	Sb-128	0.199	2.900	Pm-148	0.682	2.450
Pd-111	0.848	2.130	Sb-128A	0.346	1.000	Pm-148A	0.150	0.680
Ag-111	0.360	1.050	I -128	0.791	2.120	Nd-149	0.428	1.500
Pd-112	0.078	0.277	Sb-129	0.729	1.870	Pm-149	0.364	1.071
Ag-112	1.438	4.040	Te-129	0.498	1.590	Pm-150	0.762	3.122
In-112	0.211	0.656	I -129	0.040	0.150	Eu-150	0.309	1.070
Pd-113	1.397	3.300	I -130	0.276	1.020	Nd-151	0.617	1.995
Ag-113A	0.787	2.000	Cs-130	0.132	0.442	Pm-151	0.312	1.200
Cd-113A	0.181	0.575	Te-131	0.723	2.141	Sm-151	0.019	0.077
Pd-114	0.519	1.400	Te-131A	0.183	2.457	Pm-152	0.858	2.200
Ag-114	2.018	4.600	I -131	0.180	0.810	Eu-152	0.288	1.840
In-114	0.776	1.984	Te-132	0.047	0.220	Eu-152A	0.696	1.876
Ag-115	1.249	2.900	I -132	0.512	2.920	Pm-153	0.614	1.650
Cd-115	0.318	1.110	Te-133	0.964	2.400	Sm-153	0.233	0.804
Cd-115A	0.605	1.631	Te-133A	0.567	2.400	Pm-154	0.995	2.500
In-115	0.201	0.630	I -133	0.418	1.540	Eu-154	0.228	1.850
In-115A	0.281	0.838	Xe-133	0.099	0.343	Sm-155	0.558	1.530
Ag-116	2.211	5.000	I -134	0.663	2.410	Eu-155	0.044	0.247
In-116	1.387	3.290	Cs-134	0.152	1.453	Sm-156	0.175	0.730
In-116A	0.294	1.000	Cs-134A	0.170	0.550	Eu-156	0.425	2.447
Cd-117A	0.348	1.000	I -135	0.319	1.433	Tb-156A	0.037	0.140
In-117	0.24[illegible]	0.745	Xe-135	0.307	0.919	Eu-157	0.366	1.270
In-117A	0.641	1.764	Cs-135	0.057	0.210	Eu-158	0.060	2.650
Cd-118	0.267	0.800	Cs-136	0.108	0.657	Tb-158	0.271	0.845
In-118	1.754	4.250	Xe-137	1.522	3.600	Eu-159	0.855	2.200
In-118A	0.560	1.500	Cs-137	0.195	1.167	Gd-159	0.294	0.948
In-119	0.605	1.600	Xe-138	0.961	2.400	Eu-160	1.499	3.600
In-119A	1.061	2.650	Cs-138	1.095	3.400	Tb-160	0.189	1.700
In-120	0.876	2.200	La-138	0.056	0.205	Gd-161	0.584	1.599
In-121	1.202	2.900	Cs-139	1.600	4.000	Tb-161	0.155	0.577
In-121A	1.582	3.700	Ba-139	0.910	2.340	Ho-164	0.319	0.990
Sn-121	0.111	0.383	Ba-140	0.282	1.010	Dy-165	0.440	1.280
Sn-121A	0.150	0.420	La-140	0.490	2.200	Dy-165A	0.275	0.840
Sb-122	0.527	1.971	Ba-141	1.158	2.833	Dy-166	0.060	0.400
In-123	1.391	3.300	La-141	0.958	2.430	Ho-166	0.610	1.852
In-123A	2.013	4.600	Ce-141	0.144	0.580	Ho-166A	0.088	1.100
Sn-123	0.455	1.260	La-142	1.823	4.250	Ho-168	0.716	1.900
Sn-123A	0.540	1.420	Pr-142	0.829	2.153	Er-169	0.096	0.340
Sb-124	0.385	2.313	La-143	1.374	3.300	Ho-170	1.257	3.100
Sb-124A	1.340	3.200	Ce-143	0.371	1.380	Tm-170	0.315	0.967
Sb-124B	1.012	2.500	Pr-143	0.314	0.933	Er-171	0.355	1.490
Sn-125	0.914	2.330	Ce-144	0.081	0.320	Tm-171	0.025	0.098
Sn-125A	0.788	2.040	Pr-144	1.208	2.984	Tm-172	0.511	1.830
Sb-125	0.084	0.612	Ce-145	0.773	2.000	Tm-173	0.296	0.900
Sb-126	0.737	1.900	Pr-145	0.682	1.799	Tm-174	0.980	2.500
St-126A	0.737	1.900	Ce-146	0.224	0.700	Tm-175	0.757	2.000

A = First excited state.   B = Second excited state.

AVERAGE AND MAXIMUM BETA ENERGY BY RADIONUCLIDE--Continued

Nuclide	Energy in MeV	
	(av)	(max)
Yb-175	0.125	0.467
Tm-176	1.761	4.200
Lu-176	0.104	0.362
Yb-177	0.465	1.380
Lu-177	0.140	0.497
Lu-178	0.886	2.300
Lu-178A	0.539	1.500
Lu-179	0.476	1.350
Lu-180	1.339	3.300
Ta-180A	0.201	0.705
Hf-181	0.119	1.050
Hf-182	0.149	0.500
Ta-182	0.094	0.524
Hf-183	0.496	1.400
Ta-183	0.191	0.776
Ta-184	0.419	1.360
Ta-185	0.624	1.718
W -185	0.124	0.427
Ta-186	0.838	2.200
Re-186	0.941	1.066
W -187	0.236	1.307
W -188	0.256	0.800
Re-188	0.776	2.116
Re-189	0.237	0.750
Re-190	0.556	1.700
Re-191	0.661	1.800
Os-191	0.036	0.139
Ir-192	0.175	0.670
Ir-192A	0.431	1.500
Os-193	0.350	1.127
Ir-194	0.755	2.233
Os-195	0.746	2.000
Ir-195	0.297	1.000
Au-196	0.071	0.259
Ir-197	0.642	2.000
Pt-197	0.303	0.670
Ir-198	1.457	3.600
Au-198	0.315	1.371
Au-199	0.084	0.460
Au-200	0.669	2.210
Au-201	0.519	1.500
Au-203	0.698	1.900
Hg-203	0.057	0.212
Tl-204	0.267	0.765
Hg-205	0.590	1.650
Tl-206	0.557	1.571
Tl-207	0.503	1.441
Tl-208	0.562	2.380
Tl-209	0.733	1.990
Pb-209	0.195	0.637
Pb-210	0.005	0.061
Bi-210	0.390	1.161
Pb-211	0.443	1.390
Bi-211	0.181	0.600
Pb-212	0.106	0.586
Bi-212	0.783	2.255
Pb-214	0.214	0.980
Fr-223	0.382	1.150
Ra-225	0.089	0.320
Ac-226	0.400	1.200
Ra-227	0.444	1.310
Ac-227	0.010	0.043
Ra-228	0.014	0.055
Ra-230	0.401	1.200
Ac-230	0.807	2.200
Pa-230	0.117	0.410
Ac-231	0.765	2.100
Th-231	0.059	0.305
Th-233	0.410	1.230
Pa-233	0.063	0.568
Th-234	0.046	0.193
Pa-234	0.146	0.500
Pa-234A	0.515	1.500
Pa-234	0.476	1.400
Np-236A	0.149	0.518
U -237	0.067	0.248
Np-238	0.206	1.240
U -239	0.401	1.210
Np-239	0.135	0.723
U -240	0.101	0.360
Np-240	0.280	0.890
Np-240A	0.662	2.156
Np-241	0.458	1.360
Pu-241	0.005	0.021
Am-242	0.188	0.630
Am-244	0.510	1.500
Am-244A	0.107	0.380
Am-245	0.287	0.910
Pu-246	0.053	0.330
Bk-248	0.194	0.650
Cm-249	0.282	0.900
Bk-249	0.026	0.102
Cf-253	0.073	0.270
Es-254A	0.331	1.040

A = First excited state.

Source: O. H. Hogan, P. E. Zigman, and J. L. Mackin, *II. Spectra of Individual Negatron Emitters* (Beta Spectra, USNRDL-TR-802 [San Francisco: U.S. Naval Radiological Defense Laboratory, Dec. 16, 1964]).

SELECTED GAMMA EMITTERS BY INCREASING ENERGY

MeV	Nuclide	Half-life	Production cross section* (barns) or fission yield (%)	Yield† (%)	Daughter
0.008	Er-169	9.4d	2b	0.3	Tm-169‡
0.022	Sm-151	87y	100b	4	Eu-151‡
0.024	Sn-119m	250d	.01b	16	Sn-119‡
0.030	Ba-140	12.8d	6.3%	11	La-140
0.031	Mg- 28	21h	---	96	Al- 28
0.035	I -125	60d	---	7	Te-125‡
0.035	Te-125m	58d	5b	7	Te-125‡
0.037	Br- 80m	4.38h	2.9b	36	Br- 80
0.040	Rh-103m	57m	2.9%	0.4	Rh-103‡
0.040	I -129	1.7×10^{7} y	1.0%	9	Xe-129‡
0.047	Pb-210	21y	---	4	Bi-210
0.051	Rh-104m	4.41m	12.8b	47	Rh-104
0.053	Te-132	78h	414%	17	I -132
0.058	Gd-159	18.0h	3.5b	3	Tb-159‡
0.058	Dy-159	144d	100b	4	Tb-159‡
0.059	Te-127m	109d	0.09b	0.19	Te-127
0.060	Am-241	458y	---	36	Np-237
0.063	Yb-169	32d	11,000b	45	Tm-169‡
0.063	Th-234	24.1d	---	3.5	Pa-234m
0.068	Ta-182	115d	21b	42	W -182‡
0.068	Ti- 44	48h	---	90	Sc- 44
0.070	Sm-153	47h	210b	5.4	Eu-153‡
0.077	Pt-197	18h	1.0b	20	Au-197‡
0.077	Hg-197	65h	---	18	Au-197‡
0.078	Ti- 44	48h	---	98	Sc- 44
0.080	Ba-133	7.2y	7b	36	Cs-133‡
0.081	Ho-166	26.9h	64b	5.4	Er-166‡
0.081	Xe-133	5.27d	6.5%	37	Cs-133‡
0.084	Tm-170	130d	130b	3.3	Yb-170‡
0.084	Th-228	1.90y	---	1.6	Ra-224
0.087	Eu-155	1.81y	---	32	Gd-155‡
0.088	Pd-109-- Ag-109m	13.47h 40s	10b ---	5 ---	--- Ag-109‡

SELECTED GAMMA EMITTERS BY INCREASING ENERGY--Continued

MeV	Nuclide	Half-Life	Production cross section* (barns) or fission yield (%)	Yield† (%)	Daughter
0.088	Cd-109-- Ag-109m	453d 40s	3b ---	--- 5	--- Ag-109‡
0.088	Lu-176m	3.7h	35b	10	Hf-176‡
0.091	Nd-147	11.1d	2.6%	28	Pm-147
0.093	Th-234	24.1d	---	4	Pa-234m
0.095	Dy-165	139.2m	800b	4	Ho-165‡
0.099	Gd-153	242d	< 125b	55	Eu-153‡
0.099	Au-195	183d	---	10	Pt-195‡
0.100	Pa-234	6.75h	---	50	U -234
0.103	Sm-153	47h	210b	28	Eu-153‡
0.104	Sm-155	23m	5.5b	73	Eu-155
0.105	Eu-155	1.81y	---	20	Gd-155‡
0.113	Lu-177	6.7d	2100b	2.8	Hf-177‡
0.122	Co- 57	270d	---	87	Fe- 57‡
0.122	Eu-152	12y	5900b	37	Gd-152-- Sm-152‡
0.123	Eu-154	16y	390b	38	Gd-154‡
0.124	Ba-131	12d	8.8b	28	Cs-131
0.128	Cs-134m	2.9h	2.6b	14	Cs-134
0.129	Os-191	15d	6b	25	Ir-191‡
0.133	Hf-181	42.5d	10b	48	Ta-181‡
0.134	Ce-144	284d	6.1%	11	Pr-144
0.134	Hg-197m	24h	---	42	Hg-197
0.136	Se- 75	120.4d	30b	57	As- 75‡
0.137	Re-186	90h	110b	9	Os-186‡
0.140	Tc- 99m	6.0h	5.4%	90	Tc- 99
0.143	U -235	7.1×10^{8}y	---	11	Th-231
0.145	Ce-141	33d	6.0%	48	Pr-141‡
0.147	Ta-182m	16.5m	0.07b	40	Ta-182
0.150	Te-131	25m	2.9%	68	I -131
0.150	Cd-111m	48.6m	0.2b	30	Cd-111‡
0.150	Kr- 85m	4.4h	1.57%	74	Kr- 85-- Rb- 85‡

SELECTED GAMMA EMITTERS BY INCREASING ENERGY--Continued

MeV	Nuclide	Half-Life	Production cross section* (barns) or fission yield (%)	Yield† (%)	Daughter
0.155	Re-188	16.7h	73b	10	Os-188‡
0.158	Au-199	75.6h	---	37	Hg-199‡
0.163	Ba-140	12.8d	6.3%	6	La-140
0.164	Xe-131m	11.8d	0.02%	2	Xe-131‡
0.166	Ba-139	82.9m	6.0%	23	La-139‡
0.172	Ta-182m	16.5m	0.07b	40	Ta-182
0.185	U -235	7.1×10^{8}y	---	54	Th-231
0.186	Ra-226	1602y	---	4	Rn-222
0.191	Mo-101	14.6m	5.0%	25	Tc-101
0.191	Pt-197	18h	1.0b	6	Au-197‡
0.192	In-114m	50.0d	8b	17	Cd-114‡
0.198	Yb-169	32d	11,000b	35	Tm-169‡
0.208	Lu-177	6.7d	2100b	6.1	Hf-177‡
0.21	Ge- 77	11.3h	0.1b	61	As- 77
0.215	Hf-180m	5.5h	0.34b	82	Hf-180‡
0.215	Ru- 97	2.9d	0.2b	91	Tc- 97
0.230	Te-132	78h	4.4%	90	I -132
0.233	Xe-133m	2.26d	0.16%	14	Xe-133
0.239	Pb-212	10.64h	---	47	Bi-212
0.239	As- 77	38.7h	---	2.5	Se- 77m
0.246	Sm-155	23m	5b	4	Eu-155
0.247	Cd-111m	48.6m	0.1b	94	Cd-111‡
0.250	Xe-135	9.2h	6.2%	91	Cs-135
0.255	Sn-113	115d	0.9b	1.8	In-113m
0.263	Ge- 77	11.3h	0.1b	45	As- 77
0.265	Ge- 75	82m	0.3b	11	As- 75‡
0.265	Se- 75	120.4d	30b	60	As- 75‡
0.279	Hg-203	46.9d	4b	77	Tl-203‡
0.284	I -131	8.05d	2.9%	5.4	Xe-131m
0.286	Pm-149	53.1h	1.3%	2	Sm-149‡
0.293	Ce-143	33h	6.2%	46	Pr-143
0.295	Pb-214	26.8m	---	19	Bi-214

SELECTED GAMMA EMITTERS BY INCREASING ENERGY--Continued

MeV	Nuclide	Half-Life	Production cross section* (barns) or fission yield (%)	Yield† (%)	Daughter
0.299	Tb-160	72.1d	46b	30	Dy-160‡
0.305	Kr- 85m	4.4h	1.5%	13	Kr- 85-- Rb- 85‡
0.307	Tc-101	14.0m	5.0%	91	Ru-101‡
0.308	Er-171	7.52h	9b	63	Tm-171
0.31	Pa-233	27.0d	7.4b	44	U -233
0.317	Tr-192	74.2d	750b	81	Pt-192‡
0.319	Nd-147	11.1d	2.6%	3	Pm-147
0.320	Cr- 51	27.8d	17b	9	V - 51‡
0.325	Sn-125m	9.7m	0.1b	97	Sb-125
0.328	Ir-194	17.4h	110b	10	Pt-194‡
0.333	Hf-180m	5.5h	0.34b	93	Hf-180‡
0.335	Cd-115--	53.5h	1.1b	---	---
	In-115m	4.5h	---	50	In-115
0.342	Ag-111	7.5d	---	6	Cd-111‡
0.344	Eu-152	12y	5900b	27	Gd-152-- Sm-152‡
0.351	Bi-211	2.15m	---	14	Tl-207
0.352	Pb-214	26.8m	---	36	Bi-214
0.356	Ba-133	7.2y	7b	69	Cs-133‡
0.36	Se- 83	25m	0.004b	69	Br- 83
0.362	Pd-103	17d	4.8b	0.06	Rh-103m
0.363	Gd-159	18.0h	3.4b	9	Tb-159‡
0.364	I -131	8.05d	2.9%	82	Xe-131-- Xe-131‡
0.368	Ni- 65	2.56h	1.5b	4.5	Cu- 65‡
0.388	Sr- 87m	2.83h	1.3b	80	Sr- 87‡
0.393	Sn-113	115d	0.9b	64	In-113‡
0.393	In-113m	100m	---	64	In-113‡
0.403	Kr- 87	76m	2.7%	84	Rb- 87
0.405	Pb-211	36.1m	---	3.4	Bi-211
0.412	Au-198	2.698d	98.8b	95	Hg-198‡
0.427	Sb-125	2.7y	---	31	Sn-125
0.439	Zn- 69m	13.8h	0.1b	95	Zn- 69

SELECTED GAMMA EMITTERS BY INCREASING ENERGY--Continued

MeV	Nuclide	Half-Life	Production cross section* (barns) or fission yield (%)	Yield† (%)	Daughter
0.441	I -128	25.0m	6.3b	14	Xe-128‡
0.444	Hf-180m	5.5h	0.34b	80	Hf-180‡
0.468	Ir-192	74.2d	750b	49	Pt-192‡
0.477	Be- 7	53d	---	10.3	Li- 7‡
0.479	W -187	23.9h	38b	23	Re-187
0.482	Hf-181	42.5h	10b	81	Ta-181‡
0.487	La-140	40.22h	6.3%	40	Ce-140‡
0.49	Cd-115	53.5h	1.1b	10	In-115m
0.496	Ba-131	12d	8.8b	48	Cs-131
0.497	Ru-103	39.6d	2.9%	88	Rh-103m
0.511	Cu- 64	12.8h	4.5b	38	Ni- 64‡-- Zn- 64‡
0.511	Ga- 68	68.3m	---	176	Zn- 68‡
0.511	As- 74	17.9d	---	59	Ge- 74‡-- Se- 74‡
0.511	Na- 22	2.60y	---	180	Ne- 22‡
0.512	Ru-106--	367d	0.38%	---	---
	Rh-106	30s	---	21	Pd-106‡
0.514	Sr- 85	64d	0.8d	100	Rb- 85‡
0.514	Kr- 85	10.76y	0.3%	0.41	Rb- 85‡
0.52	Se- 83	25m	0.004b	59	Br- 83
0.527	Xe-135m	15.6m	1.8%	80	Xe-135
0.53	I -133	21h	6.5%	90	Xe-133-- Xe-133m
0.53	Cd-115	53.5h	1.1b	26	In-115m
0.533	Nd-147	11.1d	2.6%	13	Pm-147
0.537	Ba-140	12.8d	6.3%	34	La-140
0.538	I -130	12.4h	28b	99	Xe-130‡
0.554	Br- 82	35.34h	3b	66	Kr- 82‡
0.559	As- 76	26.5h	4.5b	43	Se- 76‡
0.564	Sb-122	67h	6b	66	Te-122‡
0.570	Bi-207	30y	---	98	Pb-207‡
0.583	Tl-208	3.10m	---	86	Pb-208‡

SELECTED GAMMA EMITTERS BY INCREASING ENERGY--Continued

MeV	Nuclide	Half-Life	Production cross section* (barns) or fission yield (%)	Yield† (%)	Daughter
0.596	As- 74	17.9d	---	61	Ge- 74‡-- Se- 74‡
0.599	Sb-125	2.7y	---	24	Sn-125
0.603	Sb-125	60d	3.3b	97	Te-124‡
0.605	Cs-134	2.05y	28b	98	Ba-134‡
0.609	Bi-214	19.7m	---	47	Po-214
0.619	Br- 82	35.34h	3b	41	K4- 82‡
0.622	Ru-106-- Rh-106	367d 30s	0.38% ---	--- 11	--- Pd-106‡
0.637	I -131	8.05d	2.9%	6.8	Xe-131-- Xe-131m
0.658	Ag-110m	253d	3b	96	Cd-110‡
0.658	Ag-110	24.4s	89b	4.5	Cd-110‡
0.662	Cs-137-- Ba-137m	30y 2.55m	5.9% ---	85 ---	--- Ba-137‡
0.669	I -130	12.4h	28b	100	Xe-130‡
0.67	I -132	2.3h	4.4%	144	Xe-132‡
0.686	W -187	23.9h	38b	27	Re-187
0.695	Pr-144	17.3m	6.1%	1.5	Nd-144
0.697	Te-129m	34d	0.34%	6	Te-129
0.724	Zr- 95	65d	6.4%	49	Nb- 95
0.726	Ru-105	4.44h	0.9%	48	Rh-105m-- Rh-105
0.727	Bi-212	60.6m	---	7	Tl-208-- Po-212
0.740	Mo- 99	67h	6.1%	12	Tc- 99-- Tc- 99m
0.743	I -130	12.4h	28b	87	Xe-130‡
0.747	Zr- 97-- Nb- 97m	17.0h 60s	6.2% ---	92 ---	--- Nb- 97
0.748	Sr- 91	9.67h	5.9%	27	Y - 91-- Y - 91m
0.756	Zr- 95	65d	6.4%	49	Nb- 95
0.765	Nb- 95	35d	6.4%	100	Mo- 95‡
0.773	I -132	2.3h	4.4%	89	Xe-132‡

SELECTED GAMMA EMITTERS BY INCREASING ENERGY--Continued

MeV	Nuclide	Half-Life	Production cross section* (barns) or fission yield (%)	Yield† (%)	Daughter
0.777	Br- 82	35.34h	3b	83	Kr- 82‡
0.78	Te-131m	30h	0.44%	60	Te-131 I -131
0.796	Cs-134	2.05y	28b	99	Ba-134‡
0.810	Co- 58	71.3d	---	99	Fe- 58‡
0.832	Pb-211	36.1m	---	3.4	Bi-211
0.835	Ga- 72	14.10h	5.0b	96	Ge- 72‡
0.835	Mn- 54	303d	---	100	Cr- 54‡
0.847	Mn- 56	2.58h	13.3b	99	Fe- 56‡
0.85	Te-131m	30h	0.44%	31	Te-131-- I -131
0.879	Tb-160	72.1d	46b	31	Dy-160‡
0.885	Ag-110m	253d	3b	71	Cd-110‡
0.889	Sc- 46	83.9d	13b	100	Ti- 46‡
0.898	Rb- 88	17.8m	3.7%	13	Sr- 88‡
0.90	Pa-234	6.75h	---	70	U -234
0.935	Cd-115m	43d	0.14b	1.9	Cd-115
0.966	Tb-160	72.1d	46b	31	Dy-160‡
1.02	Mo-101	14.6m	5.0%	25	Tc-101
1.025	Sr- 91	9.67h	5.9%	30	Y - 91m-- Y - 91
1.063	Bi-207	30y	---	77	Pb-207‡
1.078	Ga- 68	68.3m	---	3.5	Zn- 68‡
1.078	Rb- 86	18.66d	0.7b	8.8	Sr- 86‡
1.095	Fe- 59	45d	1.1b	56	Co- 59‡
1.115	Zn- 65	245d	0.45h	49	Cu- 65‡
1.115	Ni- 65	2.56h	1.5b	16	Cu- 65‡
1.120	Sc- 46	83.9d	13b	100	Ti- 46‡
1.120	Bi-214	19.7m	---	17	Po-214
1.122	Ta-182	115d	21b	34	W -182‡
1.14	I -135	6.7h	5.9%	37	Xe-135m-- Xe-135
1.173	Co- 60	5.26y	19b	100	Ni- 60‡
1.21	Y - 91	58.8d	5.9%	0.3%	Zr- 91‡
1.275	Na- 22	2.60y	---	100	Ne- 22‡

SELECTED GAMMA EMITTERS BY INCREASING ENERGY--Continued

MeV	Nuclide	Half-Life	Production cross section* (barns) or fission yield (%)	Yield† (%)	Daughter
1.278	Eu-154	16y	390b	37	Gd-154‡
1.28	I -135	6.7h	5.9%	34	Xe-135m-- Xe-135
1.292	Fe- 59	45d	1.1b	44	Co- 59‡
1.293	In-116m	54.0m	154b	80	Sn-116‡
1.293	Ar- 41	1.83h	.61b	99	K - 41‡
1.308	Ca- 47	4.53d	0.3b	74	Sc- 47
1.332	Co- 60	5.26y	19b	100	Ni- 60‡
1.35	Mg- 28	21h	---	70	Al- 28
1.369	Na- 24	15.0h	0.53b	100	Mg- 24‡
1.380	Ho-166	26.9h	64b	0.9	Er-166‡
1.408	Eu-152	12y	5900b	22	Gd-152-- Sm-152‡
1.426	Cs-138	32.2m	5.8%	73	Ba-138‡
1.434	V - 52	3.76m	4.9b	100	Cr- 52‡
1.460	K - 40	1.26×10^{9} y	---	11	Ca- 40‡-- Ar- 40‡
1.481	Ni- 65	2.56h	1.5b	25	Cu- 65‡
1.524	K - 42	12.4h	1.2b	18	Ca- 42‡
1.57	Pr-142	19.2h	12b	3.7	Nd-142‡
1.596	La-140	40.22h	6.3%	96	Ce-140‡
1.60	Cl- 38	37.3m	0.4b	38	Ar- 38‡
1.692	Sb-124	60d	3.3b	50	Te-124‡
1.764	Bi-214	19.7m	---	17	Po-214
1.780	Al- 28	2.31m	0.23b	100	Si- 28‡
1.811	Mn- 56	2.58h	13.3b	29	Fe- 56‡
1.863	Rb- 88	17.8m	3.7%	21	Sr- 88‡
2.614	Tl-208	3.10m	---	100	Pb-208‡
6.13	N - 16	7.2s	---	69	O - 16‡
7.11	N - 16	7.2s	---	5	O - 16‡

*Thermal neutron cross-section of target atom for nuclide of interest.
†Photon yield per disintegration.
‡Stable element.

ACTIVITY MASS RELATIONSHIP - SPECIFIC ACTIVITY

The specific activity (SpA) of a radioactive nuclide (disintegrations per unit time)/(unit mass), is calculated from the basic equation:

$$\mathrm{SpA} = \lambda N = \frac{(\ln 2)\ N}{T_{\frac{1}{2}}} .$$

Where: N = number of radioactive atoms per unit mass, and

$T_{\frac{1}{2}}$ = half-life.

This basic equation can be transformed as follows:

by definition: $N = 6.0225 \times 10^{23}/\text{atomic mass}$

$\mathrm{Ci} = 3.7 \times 10^{10}$.

Substituting : $$\mathrm{SpA} = \frac{0.69315\ N}{T_{\frac{1}{2}}\ (\text{secs})} = \frac{0.69315}{T_{\frac{1}{2}}} \times \frac{6.0225 \times 10^{23}}{\text{atomic mass}} \times \frac{1}{3.7 \times 10^{10}} = \mathrm{Ci/gm}.$$

This equation is satisfactory when the half-life of the nuclide is expressed in seconds. If, however, the half-life is expressed in other units (such as minutes, hours, days, or years), a separate time conversion is required for each. By substituting the appropriate time conversion factors the following five equations can be obtained.

$$\text{curies/gram or SpA } (T_{\frac{1}{2}} \text{ in secs}) = \frac{1.128 \times 10^{13}}{(T_{\frac{1}{2}})(\text{atomic mass})} \quad (1)$$

$$\text{curies/gram or SpA } (T_{\frac{1}{2}} \text{ in mins}) = \frac{1.880 \times 10^{11}}{(T_{\frac{1}{2}})(\text{atomic mass})} \quad (2)$$

$$\text{curies/gram or SpA } (T_{\frac{1}{2}} \text{ in hrs}) = \frac{3.134 \times 10^{9}}{(T_{\frac{1}{2}})(\text{atomic mass})} \quad (3)$$

$$\text{curies/gram or SpA } (T_{\frac{1}{2}} \text{ in days}) = \frac{1.306 \times 10^{8}}{(T_{\frac{1}{2}})(\text{atomic mass})} \quad (4)$$

$$\text{curies/gram or SpA } (T_{\frac{1}{2}} \text{ in yrs}) = \frac{3.578 \times 10^{5}}{(T_{\frac{1}{2}})(\text{atomic mass})} \quad (5)$$

Example: Calculate the specific activity of ^{131}I whose half-life is 8.05d. Using equation (4) and the mass number as the atomic mass, make the appropriate substitutions:

$$\mathrm{SpA} = \frac{1.306 \times 10^{8}}{8.05 \times 131} = 1.24 \times 10^{5}$$

The following specific activities were calculated from the above equations, using half-lives from The Table of Isotopes.[1] Integer mass numbers were used rather than actual masses, except for ^{3}H where the exact mass was used. (It should be noted that these specific activities are for pure forms of the nuclides only.) More extensive tables of specific activities are available.[2]

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[1] Lederer, C. M., Hollander, J. M., and Perlman, I., The Table of Isotopes, (6th ed.; New York: John Wiley & Sons, Inc., 1967).

[2] Goldstein, G., and Reynolds, S. A., "Specific Activities and Half-Lives of Common Radionuclides," Nuclear Data A, Vol. 1, No. 5 (July 1966), pp.435-452.

SPECIFIC ACTIVITY

Radionuclide	Half-Life	Curies per gram	Radionuclide	Half-Life	Curies per gram
Hydrogen-3	12.3y	9.64×10^{3}	Molybdenum-99	67h	4.72×10^{5}
Carbon-14	5730y	4.46	Technetium-99m	6.0h	5.28×10^{6}
Nitrogen-16	7.2s	9.79×10^{10}	Ruthenium-106	367d	3.36×10^{3}
Sodium-22	2.60y	6.25×10^{3}	Iodine-125	60d	1.74×10^{4}
Sodium-24	15.0h	8.71×10^{6}	Iodine-130	12.4h	1.94×10^{6}
Phosphorus-32	14.3d	2.85×10^{5}	Iodine-131	8.05d	1.24×10^{5}
Sulfur-35	88d	4.24×10^{4}	Barium-133	7.2y	374
Chlorine-36	3.1×10^{5}y	3.21×10^{-2}	Cesium-134	2.05y	1.30×10^{3}
Argon-41	1.83h	4.18×10^{7}	Cesium-137	30.0y	87.0
Potassium-42	12.4h	6.02×10^{6}	Barium-140	12.8d	7.29×10^{4}
Calcium-45	165d	1.76×10^{4}	Lanthanum-140	40.22h	5.57×10^{5}
Chromium-51	27.8d	9.21×10^{4}	Cerium-141	33d	2.81×10^{4}
Manganese-54	303d	7.98×10^{3}	Cerium-144	284d	3.19×10^{3}
Iron-55	2.6y	2.50×10^{3}	Praseodymium-144	17.3m	7.55×10^{7}
Manganese-56	2.576h	2.17×10^{7}	Promethium-147	2.62y	929
Cobalt-57	270d	8.48×10^{3}	Tantalum-182	115d	6.24×10^{3}
Iron-59	45d	4.92×10^{4}	Tungsten-185	75d	9.41×10^{3}
Nickel-59	8×10^{4}y	7.58×10^{-2}	Iridium-192	74.2d	9.17×10^{3}
Cobalt-60	5.26y	1.13×10^{3}	Gold-198	64.8h	2.44×10^{5}
Nickel-63	92y	61.7	Gold-199	75.6h	2.08×10^{5}
Copper-64	12.8h	3.83×10^{6}	Mercury-203	46.9d	1.37×10^{4}
Zinc-65	245d	8.20×10^{3}	Thallium-204	3.8y	462
Gallium-72	14.1h	3.09×10^{6}	Polonium-210	138.4d	4.49×10^{3}
Arsenic-76	26.5h	1.56×10^{6}	Polonium-212	304ns	1.75×10^{17}
Bromine-82	35.34h	1.08×10^{6}	Radium-226	1602y	0.988
Rubidium-86	18.66d	8.14×10^{4}	Thorium-232	1.41×10^{10}y	1.09×10^{-7}
Strontium-89	52d	2.82×10^{4}	Uranium-233	1.62×10^{5}y	9.48×10^{-3}
Strontium-90	28.1y	141	Thorium-234	24.1d	2.32×10^{4}
Yttrium-90	64h	5.44×10^{5}	Uranium-234	7.1×10^{8}y	2.14×10^{-6}
Yttrium-91	58.8d	2.44×10^{4}	Uranium-238	4.51×10^{9}y	3.33×10^{-7}
			Plutonium-239	2.44×10^{4}y	6.13×10^{-2}

UNIVERSAL DECAY TABLE

The following table gives the fraction of activity of a nuclide remaining, from .001 half-life to 1.000 half-life.

To use this table:

1. Divide elapsed time by half-life ($t/T_{\frac{1}{2}}$). Time must be in the same units.
2. With the answer obtained in Step 1, enter appropriate row along the side and the column at the top. The number obtained is the fraction of original activity remaining.
3. Multiply original activity by this figure to obtain present activity (or the amount remaining).

Example:

What is the strength of a 210 mCi PoBe source after 180 days? ($T_{\frac{1}{2}}$ for PoBe = 138.2 days.)

1. The source has gone 42 days past 1.000 half-life, therefore 42/138.2 = .303.
2. Entering the .300 row from the left and the .003 column from the top gives .81060 as the fraction remaining.
3. Therefore, 210/2 = 105 mCi for 1.000 half-life and 105 mCi X .81060 = 85.11 mCi for the amount remaining at the end of 180 days.

UNIVERSAL DECAY TABLE

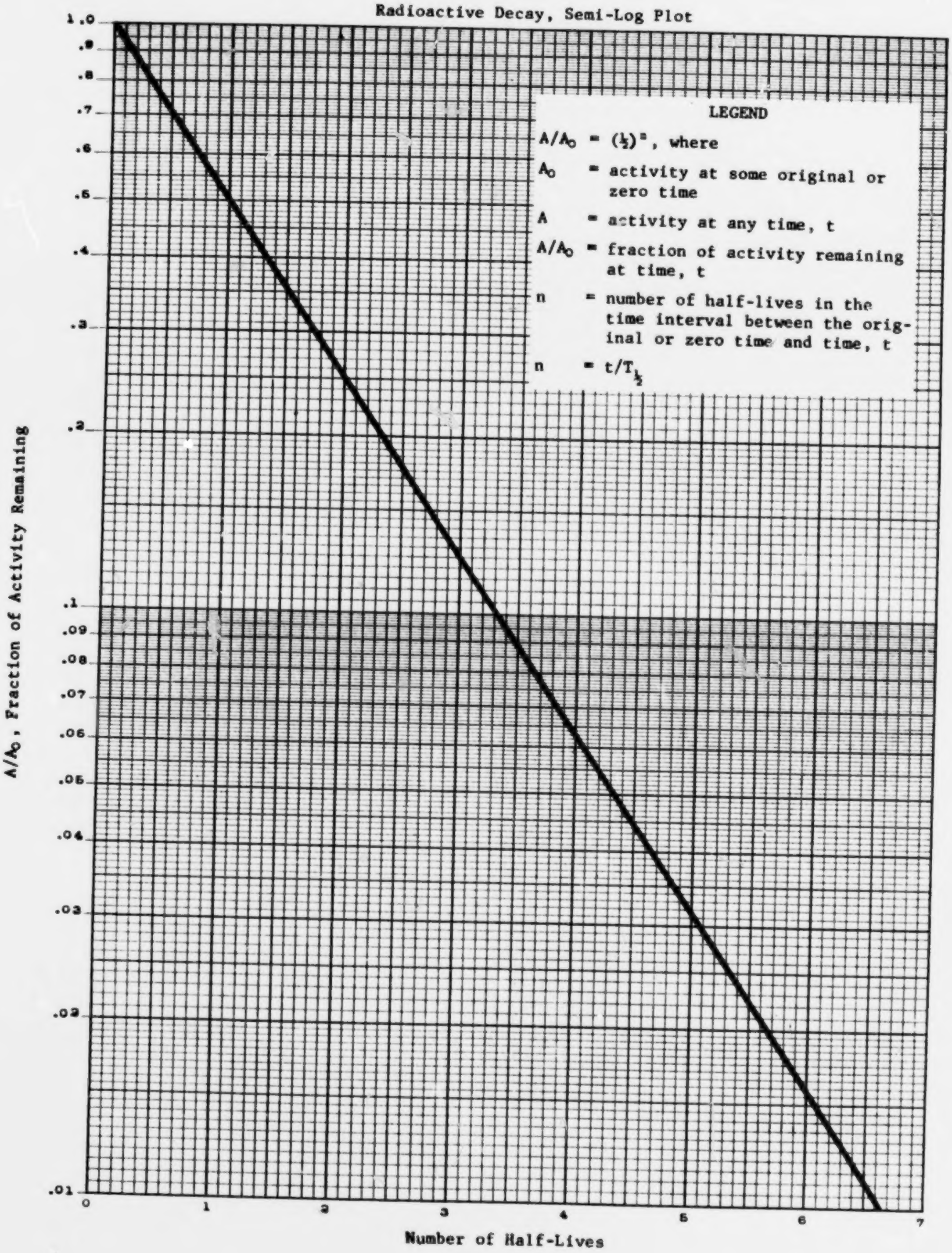
ACTIVITY REMAINING FOR $t/T_{\frac{1}{2}}$ FROM .001 TO 1.00

	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
.000	.00000	.99969	.99862	.99793	.99723	.99645	.99586	.99516	.99446	.99379
.010	.99309	.99238	.99172	.99103	.99034	.98966	.98898	.98828	.98759	.98693
.020	.98623	.98554	.98487	.98419	.98350	.98243	.98214	.98146	.98076	.98010
.030	.97942	.97874	.97807	.97740	.97671	.97603	.97517	.97446	.97399	.97333
.040	.97262	.97299	.97132	.97065	.96997	.96930	.96880	.96795	.96726	.96662
.050	.96594	.96527	.96461	.96393	.96326	.96260	.96190	.96125	.96058	.95994
.060	.95928	.95862	.95795	.95728	.95661	.95596	.95529	.95452	.95395	.95331
.070	.95264	.95199	.95133	.95067	.95000	.94936	.94870	.94800	.94738	.94673
.080	.94587	.94522	.94457	.94392	.94326	.94261	.94196	.94130	.94063	.94000
.090	.93926	.93888	.93833	.93759	.93693	.93628	.93564	.93499	.93434	.93370
.100	.93304	.93240	.93175	.93112	.93046	.92982	.92906	.92853	.92887	.92725
.110	.92660	.92596	.92532	.92468	.92403	.92340	.92276	.92216	.92152	.92085
.120	.92020	.91956	.91893	.91785	.91766	.91702	.91639	.91575	.91511	.91448
.130	.91339	.91321	.91265	.91196	.91132	.91069	.91008	.90939	.90841	.90817
.140	.90747	.90691	.90629	.95066	.90502	.90440	.90378	.90314	.90250	.90190
.150	.90127	.90064	.90002	.89931	.89840	.89816	.89754	.89690	.89627	.89566
.160	.89504	.89442	.89381	.89319	.89257	.89195	.89133	.89071	.89008	.88949
.170	.88888	.88825	.88763	.88702	.88650	.88579	.88518	.88456	.88393	.88334
.180	.88272	.88211	.88150	.88098	.88030	.87967	.87905	.87885	.87852	.87724
.190	.87663	.87602	.87542	.87481	.87420	.87320	.87300	.87216	.87178	.87118
.200	.87057	.86997	.86937	.86877	.86816	.86756	.86697	.86636	.86576	.86517
.210	.86456	.86396	.86337	.86277	.86217	.86157	.86082	.86037	.85978	.85919
.220	.85859	.85800	.85741	.85681	.85621	.85579	.85503	.85443	.85384	.85326
.230	.85266	.85207	.85148	.85097	.85030	.84975	.84914	.84853	.84794	.84736
.240	.84677	.84619	.84561	.84502	.84443	.84384	.84326	.84268	.84210	.84152
.250	.84092	.84034	.83976	.83918	.83860	.83802	.83744	.83685	.83628	.83570
.260	.83511	.83454	.83396	.83339	.83283	.83223	.83208	.83166	.83050	.82993
.270	.82935	.82875	.82820	.82763	.82705	.82648	.82591	.82533	.82476	.82419
.280	.82362	.82313	.82248	.82191	.82136	.82077	.82021	.81962	.81907	.81850
.290	.81792	.81736	.81681	.81624	.81567	.81511	.81454	.81397	.81341	.81300
.300	.81228	.81172	.81116	.81060	.81004	.80948	.80892	.80819	.80779	.80702
.310	.80667	.80609	.80556	.80500	.80444	.80489	.80333	.80277	.80222	.80166
.320	.80110	.80055	.80000	.79944	.79888	.79834	.79779	.79731	.79668	.79613
.330	.79557	.79502	.79447	.79392	.79337	.79282	.79227	.79172	.79118	.79063
.340	.79007	.78953	.78899	.78844	.78789	.78735	.78681	.78625	.78571	.78517
.350	.78462	.78408	.78354	.78300	.78245	.78191	.78137	.78082	.78028	.77974
.360	.77920	.77866	.77813	.77759	.77704	.77648	.77597	.77543	.77489	.77436
.370	.77383	.77329	.77275	.77222	.77168	.77115	.77062	.77007	.76593	.76901
.380	.76848	.76795	.76742	.76689	.76635	.76582	.76529	.76476	.76423	.76370
.390	.76317	.76272	.76212	.76159	.76106	.76053	.76001	.75948	.75895	.75843
.400	.75790	.75737	.75685	.75633	.75580	.75528	.75476	.75423	.75371	.75319
.410	.75266	.75215	.75163	.75111	.75058	.75006	.74955	.74902	.74856	.74799
.420	.74747	.74695	.74644	.74592	.74540	.74488	.74437	.74385	.74334	.74282
.430	.74231	.74179	.74128	.74077	.74025	.73974	.73923	.73871	.73820	.73762
.440	.73718	.73667	.73616	.73568	.73514	.73463	.73413	.73361	.73311	.73260
.450	.73208	.73258	.73108	.73057	.73006	.72956	.72958	.72854	.72804	.72754
.460	.72708	.72653	.72603	.72545	.72527	.72452	.72402	.72351	.72302	.72252
.470	.72201	.72151	.72102	.72052	.72001	.71952	.71902	.71852	.71802	.71753
.480	.71702	.71653	.71604	.71554	.71504	.71455	.71405	.71355	.71306	.71257
.490	.71207	.71158	.71109	.71060	.71010	.70961	.70912	.70863	.70814	.70765
.500	.70715	.70666	.70618	.70569	.70520	.70471	.70423	.70373	.70325	.70276

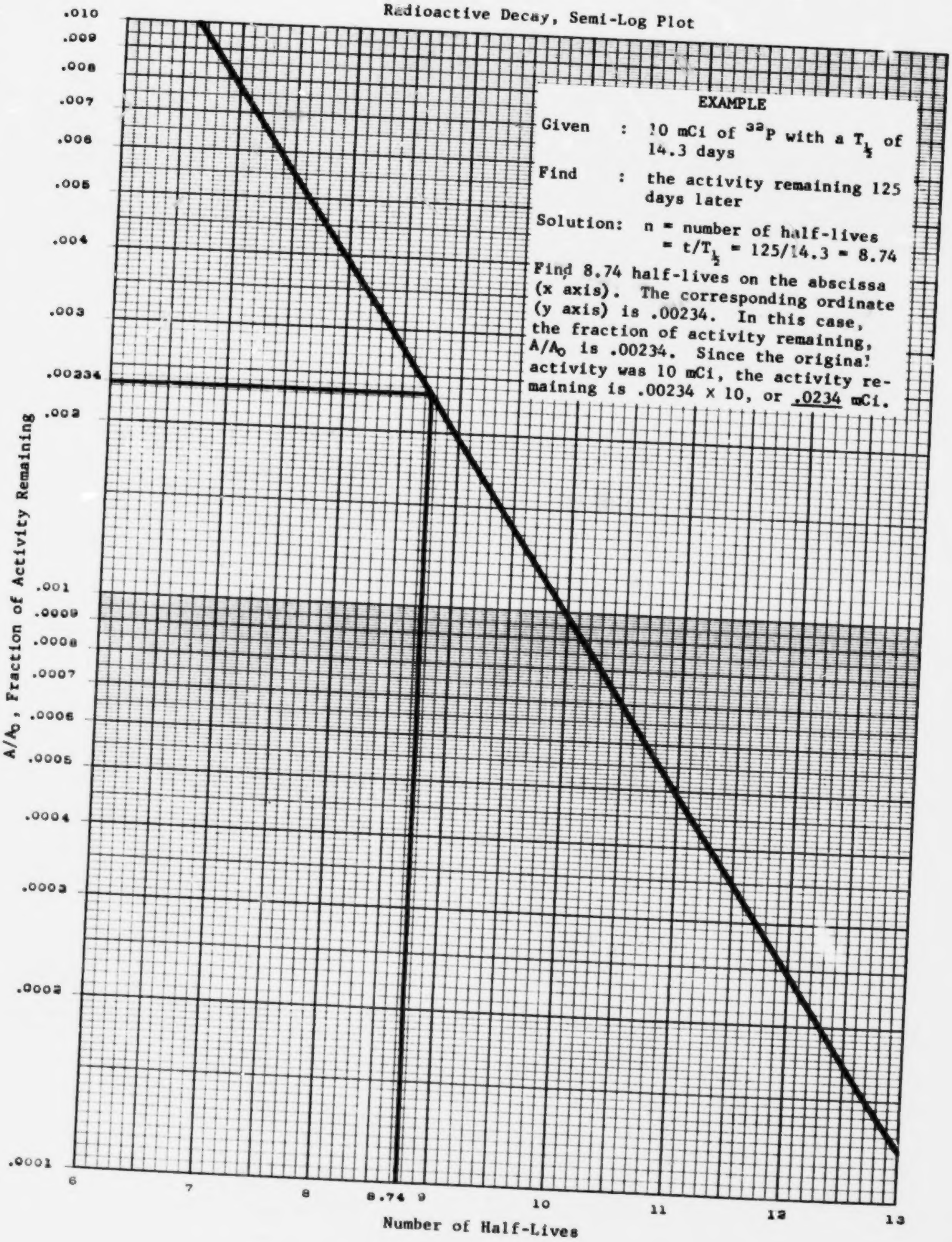
UNIVERSAL DECAY TABLE--Continued

ACTIVITY REMAINING FOR $t/T_{\frac{1}{2}}$ FROM .001 TO 1.00

	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
.510	.70227	.70179	.70130	.70082	.70033	.69984	.69936	.69887	.69839	.69791
.520	.69742	.69694	.69646	.69598	.69549	.69501	.69453	.69404	.69356	.69309
.530	.69261	.69213	.69165	.69117	.69069	.69021	.68973	.68925	.68871	.68830
.540	.68796	.68735	.68687	.68640	.68593	.68545	.68497	.68450	.68395	.68348
.550	.68307	.68260	.68213	.68166	.68118	.68071	.68024	.67976	.67913	.67882
.560	.66835	.67782	.67742	.67695	.67646	.67601	.67554	.67507	.67461	.67414
.570	.67367	.67320	.67274	.67227	.67181	.67134	.67088	.67041	.66995	.66948
.580	.66902	.66856	.66810	.66764	.66718	.66671	.66624	.66578	.66532	.66486
.590	.66440	.66394	.66348	.66302	.66256	.66210	.66164	.66118	.66053	.66027
.600	.65981	.65935	.65890	.65846	.65798	.65753	.65707	.65661	.65616	.65571
.610	.65525	.65480	.65435	.65390	.65344	.65299	.65244	.65208	.65163	.65118
.620	.65073	.65028	.64983	.64938	.64892	.64848	.64803	.64758	.64713	.64669
.630	.64623	.64598	.64534	.64489	.64448	.64400	.64356	.64310	.64273	.64222
.640	.64178	.64133	.64089	.64044	.64000	.63955	.63911	.63886	.63822	.63778
.650	.63764	.63690	.63646	.63602	.63558	.63514	.63470	.63425	.63382	.63338
.660	.63293	.63250	.63206	.63163	.63118	.63075	.63032	.62987	.62944	.62900
.670	.62856	.62813	.62770	.62727	.62683	.62639	.62588	.62552	.62509	.62466
.680	.62422	.62379	.62336	.62293	.62250	.62207	.62164	.62120	.62077	.62035
.690	.61991	.61936	.61906	.61863	.61820	.61777	.61736	.61691	.61649	.61606
.700	.61563	.61520	.61478	.61436	.61393	.61350	.61308	.61265	.61223	.61181
.710	.61138	.61096	.61054	.61012	.60969	.60927	.60885	.60842	.60800	.60758
.720	.60716	.60674	.60632	.60572	.60548	.60506	.60464	.60422	.60380	.60339
.730	.60296	.60255	.60213	.60172	.60130	.60088	.60047	.60005	.59963	.59922
.740	.59880	.59838	.59797	.59756	.59717	.59673	.59632	.59590	.59549	.59508
.750	.59466	.59426	.59385	.59344	.59302	.59261	.59220	.59179	.59144	.59097
.760	.59053	.59015	.58974	.58934	.58892	.58852	.58811	.58770	.58730	.58690
.770	.58648	.58608	.58567	.58527	.58485	.58477	.58405	.58364	.58324	.58271
.780	.58243	.58202	.58163	.58122	.58082	.58042	.58002	.57961	.57921	.57910
.790	.57841	.57801	.57761	.57721	.57681	.57641	.57601	.57561	.57579	.57438
.800	.57441	.57402	.59362	.57317	.57282	.57243	.57204	.57163	.57124	.57085
.810	.57045	.57005	.56966	.56904	.56886	.56847	.56808	.56768	.56729	.56690
.820	.56645	.56611	.56572	.56533	.56494	.56455	.56416	.56377	.56338	.56299
.830	.56359	.56320	.56282	.56243	.56203	.56165	.56126	.56087	.56049	.56010
.840	.55899	.55832	.55794	.55755	.55716	.55678	.55640	.55601	.55562	.55524
.850	.55485	.55447	.55408	.55370	.55328	.55293	.55255	.55217	.55179	.55140
.860	.55102	.55064	.55026	.54988	.54950	.54912	.54874	.54841	.54797	.54760
.870	.54721	.54683	.54646	.54605	.54565	.54532	.54495	.54457	.54419	.54382
.880	.54344	.54306	.54269	.54231	.54193	.54156	.54118	.54081	.54043	.54006
.890	.53968	.53931	.53894	.53856	.53819	.53782	.53745	.53702	.53670	.53633
.900	.53595	.53558	.53538	.53485	.53447	.53410	.53373	.53336	.53299	.53262
.910	.53225	.53188	.53152	.53115	.53078	.53043	.53005	.52968	.52931	.52895
.920	.52858	.52821	.52785	.52748	.52711	.52675	.52638	.52600	.52566	.52529
.930	.52493	.52456	.52420	.52384	.52347	.52311	.52275	.52239	.52203	.52168
.940	.52130	.52094	.52058	.52022	.51986	.51950	.51916	.51898	.51842	.51806
.950	.51770	.51734	.51698	.51641	.51627	.51591	.51556	.51520	.51484	.51448
.960	.51402	.51377	.51342	.51306	.51270	.51235	.51200	.51164	.51129	.51093
.970	.51057	.51027	.50987	.50952	.50918	.50881	.50846	.50810	.50775	.50740
.980	.50715	.50670	.50635	.50600	.50570	.50530	.50495	.50460	.50426	.50390
.990	.50355	.50320	.50285	.50256	.50216	.50181	.50141	.50111	.50077	.50042
1.000	.50000	.49973	.49938	.49904	.49869	.49838	.49860	.49765	.49731	.49697



Radioactive Decay, Semi-Log Plot



Radioactive Decay, Semi-Log Plot

EXAMPLE

Given : 10 mCi of ^{32}P with a $T_{\frac{1}{2}}$ of 14.3 days

Find : the activity remaining 125 days later

Solution: n = number of half-lives
$= t/T_{\frac{1}{2}} = 125/14.3 = 8.74$

Find 8.74 half-lives on the abscissa (x axis). The corresponding ordinate (y axis) is .00234. In this case, the fraction of activity remaining, A/A_0 is .00234. Since the original activity was 10 mCi, the activity remaining is .00234 × 10, or .0234 mCi.

.010
.009
.008
.007
.006
.005
.004
.003
.00234
.002
.001
.0009
.0008
.0007
.0006
.0005
.0004
.0003
.0002
.0001
A/A$_0$, Fraction of Activity Remaining
6
7
8
8.74
9
10
11
12
13
Number of Half-Lives

Thorium Series (4n)*

Nuclide	Historical name	Half-life	Major radiation energies (MeV) and intensities†		
			α	β	γ
$^{232}_{90}$Th	Thorium	1.41×10^{10}y	3.95 (24%) 4.01 (76%)	---	---
$^{228}_{88}$Ra	Mesothorium I	6.7y	---	0.055 (100%)	---
$^{228}_{89}$Ac	Mesothorium II	6.13h	---	1.18 (35%) 1.75 (12%) 2.09 (12%)	0.34c‡ (15%) 0.908 (25%) 0.96c (20%)
$^{228}_{90}$Th	Radiothorium	1.910y	5.34 (28%) 5.43 (71%)	---	0.084 (1.6%) 0.214 (0.3%)
$^{224}_{88}$Ra	Thorium X	3.64d	5.45 (6%) 5.68 (94%)	---	0.241 (3.7%)
$^{220}_{86}$Rn	Emanation Thoron (Tn)	55s	6.29 (100%)	---	0.55 (0.07%)
$^{216}_{84}$Po	Thorium A	0.15s	6.78 (100%)	---	---
$^{212}_{82}$Pb	Thorium B	10.64h	---	0.346 (81%) 0.586 (14%)	0.239 (47%) 0.300 (3.2%)
$^{212}_{83}$Bi 64.0% 36.0%	Thorium C	60.6m	6.05 (25%) 6.09 (10%)	1.55 (5%) 2.26 (55%)	0.040 (2%) 0.727 (7%) 1.620 (1.8%)
$^{212}_{84}$Po	Thorium C'	304ns	8.78 (100%)	---	---
$^{208}_{81}$Tl	Thorium C"	3.10m	---	1.28 (25%) 1.52 (21%) 1.80 (50%)	0.511 (23%) 0.583 (86%) 0.860 (12%) 2.614 (100%)
$^{208}_{82}$Pb	Thorium D	Stable	---	---	---

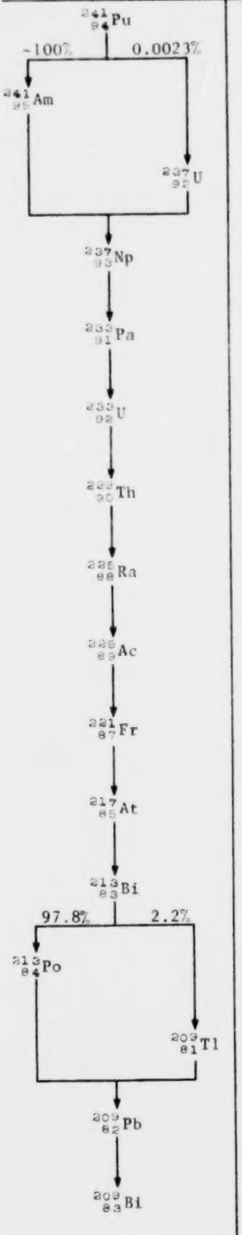
*This expression describes the mass number of any member in this series, where n is an integer.
Example: $^{232}_{90}$Th (4n)......4(58) = 232

†Intensities refer to percentage of disintegrations of the nuclide itself, not to original parent of series.

‡Complex energy peak which would be incompletely resolved by instruments of moderately low resolving power such as scintillators.

Data taken from: Lederer, C. M., Hollander, J. M., and Perlman, I., Table of Isotopes (6th ed.; New York: John Wiley & Sons, Inc., 1967) and Hogan, O. H., Zigman, P. E., and Mackin, J. L., Beta Spectra (USNRDL-TR-802 [Washington, D.C.: U.S. Atomic Energy Commission, 1964]).

Neptunium Series (4n + 1)*



Nuclide	Element name	Half-life	Major radiation energies (MeV) and intensities†		
			α	β	γ
$^{241}_{94}$Pu	Plutonium	13.2y	4.85 (0.0003%) 4.90 (0.0019%)	0.021 (~100%)	0.145 (.00016%)
$^{241}_{95}$Am	Americium	458y	5.44 (13%) 5.49 (85%)	---	0.060 (36%) 0.101c‡ (0.04%)
$^{237}_{92}$U	Uranium	6.75d	---	0.248 (96%)	0.060 (36%) 0.208 (23%)
$^{237}_{93}$Np	Neptunium	2.14×10^{6}y	4.65c (12%) 4.78c (75%)	---	0.030 (14%) 0.086 (14%) 0.145 (1%)
$^{233}_{91}$Pa	Protactinium	27.0d	---	0.145 (37%) 0.257 (58%) 0.568 (5%)	0.31c (44%)
$^{233}_{92}$U	Uranium	1.62×10^{5}y	4.78 (15%) 4.82 (83%)	---	0.042 (?) 0.097 (?)
$^{229}_{90}$Th	Thorium	7340y	4.84 (58%) 4.90 (11%) 5.05 (7%)	---	0.137c (~3%) 0.20c (~10%)
$^{225}_{88}$Ra	Radium	14.8d	---	0.32 (100%)	0.040 (33%)
$^{225}_{89}$Ac	Actinium	10.0d	5.73c (10%) 5.79 (28%) 5.83 (54%)	---	0.099 (?) 0.150 (?) 0.187 (?)
$^{221}_{87}$Fr	Francium	4.8m	6.12 (15%) 6.34 (82%)	---	0.218 (14%)
$^{217}_{85}$At	Astatine	0.032s	7.07 (~100%)	---	---
$^{213}_{83}$Bi	Bismuth	47m	5.87 (~2.2%)	1.39 (~97.8%)	0.437 (?)
$^{213}_{84}$Po	Polonium	4.2μs	8.38 (~100%)	---	---
$^{209}_{81}$Tl	Thallium	2.2m	---	1.99 (100%)	0.12 (50%) 0.45 (100%) 1.56 (100%)
$^{209}_{82}$Pb	Lead	3.30h	---	0.637 (100%)	---
$^{209}_{83}$Bi	Bismuth	Stable (>2×10^{18}y)	---	---	---

*This expression describes the mass number of any member in this series, where n is an integer.
Example: $^{229}_{90}$Th (4n + 1)......4(57) + 1 = 229
The (4n + 1) series is included here for completion. It is not found as a naturally-occurring series.
†Intensities refer to percentage of disintegrations of the nuclide itself, not to original parent of series.
‡Complex energy peak which would be incompletely resolved by instruments of moderately low resolving power such as scintillators.

Data taken from: Table of Isotopes and USNRDL-TR-802.

Uranium Series (4n + 2)*

Nuclide	Historical name	Half-life	Major radiation energies (MeV) and intensities†		
			α	β	γ
$^{238}_{92}$U	Uranium I	4.51×10^{9}y	4.15 (25%) 4.20 (75%)	---	---
$^{234}_{90}$Th	Uranium X$_1$	24.1d	---	0.103 (21%) 0.19 (79%)	0.063c‡ (3.5%) 0.093c (4%)
$^{234}_{91}$Pa^{m} 99.87% | 0.13%	Uranium X$_2$	1.17m	---	2.29 (98%)	0.765 (0.30%) 1.001 (0.60%)
$^{234}_{91}$Pa	Uranium Z	6.75h	---	0.53 (66%) 1.13 (13%)	0.100 (50%) 0.70 (24%) 0.90 (70%)
$^{234}_{92}$U	Uranium II	2.47×10^{5}y	4.72 (28%) 4.77 (72%)	---	0.053 (0.2%)
$^{230}_{90}$Th	Ionium	8.0 ×10^{4}y	4.62 (24%) 4.68 (76%)	---	0.068 (0.6%) 0.142 (0.07%)
$^{226}_{88}$Ra	Radium	1602y	4.60 (6%) 4.78 (95%)	---	0.186 (4%)
$^{222}_{86}$Rn	Emanation Radon (Rn)	3.823d	5.49 (100%)	---	0.510 (0.07%)
$^{218}_{84}$Po 99.98% | 0.02%	Radium A	3.05m	6.00 (~100%)	0.33 (~0.019%)	---
$^{214}_{82}$Pb	Radium B	26.8m	---	0.65 (50%) 0.71 (40%) 0.98 (6%)	0.295 (19%) 0.352 (36%)
$^{218}_{85}$At	Astatine	~2s	6.65 (6%) 6.70 (94%)	? (~0.1%)	---
$^{214}_{83}$Bi 99.98% | 0.02%	Radium C	19.7m	5.45 (0.012%) 5.51 (0.008%)	1.0 (23%) 1.51 (40%) 3.26 (19%)	0.609 (47%) 1.120 (17%) 1.764 (17%)
$^{214}_{84}$Po	Radium C'	164μs	7.69 (100%)	---	0.799 (0.014%)
$^{210}_{81}$Tl	Radium C"	1.3m	---	1.3 (25%) 1.9 (56%) 2.3 (19%)	0.296 (80%) 0.795 (100%) 1.31 (21%)
$^{210}_{82}$Pb	Radium D	21y	3.72 (.000002%)	0.016 (85%) 0.061 (15%)	0.047 (4%)
$^{210}_{83}$Bi ~100% | .00013%	Radium E	5.01d	4.65 (.00007%) 4.69 (.00005%)	1.161 (~100%)	---
$^{210}_{84}$Po	Radium F	138.4d	5.305 (100%)	---	0.803 (0.0011%)
$^{206}_{81}$Tl	Radium E"	4.19m	---	1.571 (100%)	---
$^{206}_{82}$Pb	Radium G	Stable	---	---	---

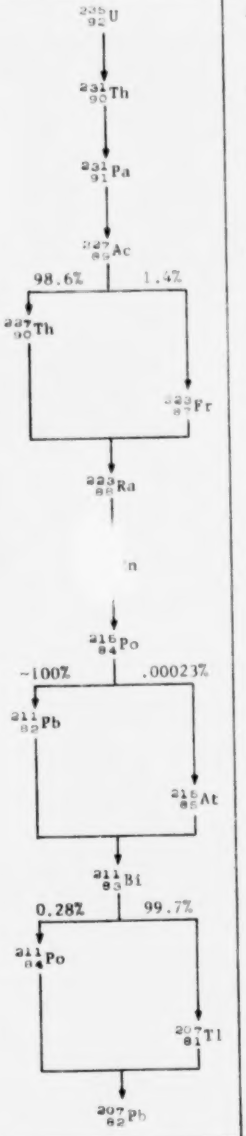
*This expression describes the mass number of any member in this series, where n is an integer.
Example: $^{206}_{82}$Pb (4n + 2)......4(51) + 2 = 206

†Intensities refer to percentage of disintegrations of the nuclide itself, not to original parent of series.

‡Complex energy peak which would be incompletely resolved by instruments of moderately low resolving power such as scintillators.

Data taken from: Table of Isotopes and USNRDL-TR-802.

Actinium Series (4n + 3)*



Nuclide	Historical name	Half-life	Major radiation energies (MeV) and intensities†		
			α	β	γ
$^{235}_{92}U$	Actinouranium	7.1×10^8y	4.37 (18%) 4.40 (57%) 4.58c‡ (8%)	---	0.143 (11%) 0.185 (54%) 0.204 (5%)
$^{231}_{90}Th$	Uranium Y	25.5h	---	0.140 (45%) 0.220 (15%) 0.305 (40%)	0.026 (2%) 0.084c (10%)
$^{231}_{91}Pa$	Protoactinium	3.25×10^4y	4.95 (22%) 5.01 (24%) 5.02 (23%)	---	0.027 (6%) 0.29c (6%)
$^{227}_{89}Ac$	Actinium	21.6y	4.86c (0.18%) 4.95c (1.2%)	0.043 (~99%)	0.070 (0.08%)
$^{227}_{90}Th$	Radioactinium	18.2d	5.76 (21%) 5.98 (24%) 6.04 (23%)	---	0.050 (8%) 0.237c (15%) 0.31c (8%)
$^{223}_{87}Fr$	Actinium K	22m	5.44 (~0.005%)	1.15 (~100%)	0.050 (40%) 0.080 (13%) 0.234 (4%)
$^{223}_{88}Ra$	Actinium X	11.43d	5.61 (26%) 5.71 (54%) 5.75 (9%)	---	0.149c (10%) 0.270 (10%) 0.33c (6%)
n	Emanation Actinon (An)	4.0s	6.42 (8%) 6.55 (11%) 6.82 (81%)	---	0.272 (9%) 0.401 (5%)
$^{215}_{84}Po$	Actinium A	1.78ms	7.38 (~100%)	0.74 (~.00023%)	---
$^{211}_{82}Pb$	Actinium B	36.1m	---	0.29 (1.4%) 0.56 (9.4%) 1.39 (87.5%)	0.405 (3.4%) 0.427 (1.8%) 0.832 (3.4%)
$^{215}_{85}At$	Astatine	~0.1ms	8.01 (~100%)	---	---
$^{211}_{83}Bi$	Actinium C	2.15m	6.28 (16%) 6.62 (84%)	0.60 (0.28%)	0.351 (14%)
$^{211}_{84}Po$	Actinium C'	0.52s	7.45 (99%)	---	0.570 (0.5%) 0.90 (0.5%)
$^{207}_{81}Tl$	Actinium C"	4.79m	---	1.44 (99.8%)	0.897 (0.16%)
$^{207}_{82}Pb$	Actinium D	Stable	---	---	---

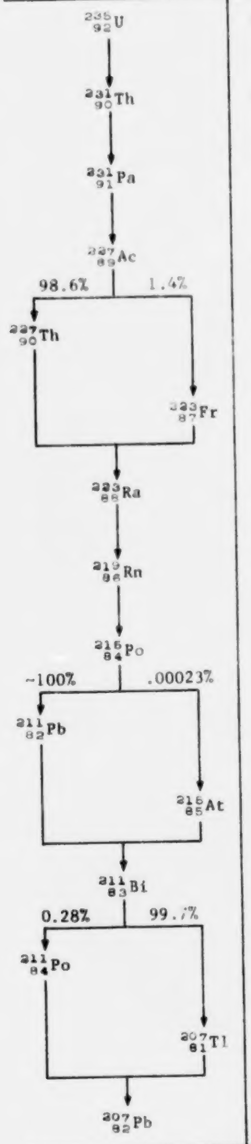
*This expression describes the mass number of any member in this series, where n is an integer.
Example: $^{207}_{82}Pb$ (4n + 3)......4(51) + 3 = 207

†Intensities refer to percentage of disintegrations of the nuclide itself, not to original parent of series.

‡Complex energy peak which would be incompletely resolved by instruments of moderately low resolving power such as scintillators.

Data taken from: Table of Isotopes and USNRDL-TR-802.

Actinium Series (4n + 3)*



Nuclide	Historical name	Half-life	Major radiation energies (MeV) and intensities†		
			α	β	γ
$^{235}_{92}U$	Actinouranium	7.1 ×10^{8}y	4.37 (18%) 4.40 (57%) 4.58c‡ (8%)	---	0.143 (11%) 0.185 (54%) 0.204 (5%)
$^{231}_{90}Th$	Uranium Y	25.5h	---	0.140 (45%) 0.220 (15%) 0.305 (40%)	0.026 (2%) 0.084c (10%)
$^{231}_{91}Pa$	Protoactinium	3.25x10^{4}y	4.95 (22%) 5.01 (24%) 5.02 (23%)	---	0.027 (6%) 0.29c (6%)
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$^{219}_{86}Rn$	Emanation Actinon (An)	4.0s	6.42 (8%) 6.55 (11%) 6.82 (81%)	---	0.272 (9%) 0.401 (5%)
$^{215}_{84}Po$	Actinium A	1.78ms	7.38 (~100%)	0.74 (~.00023%)	---
$^{211}_{82}Pb$	Actinium B	36.1m	---	0.29 (1.4%) 0.56 (9.4%) 1.39 (87.5%)	0.405 (3.4%) 0.427 (1.8%) 0.832 (3.4%)
$^{215}_{85}At$	Astatine	~0.1ms	8.01 (~100%)	---	---
$^{211}_{83}Bi$	Actinium C	2.15m	6.28 (16%) 6.62 (84%)	0.60 (0.28%)	0.351 (14%)
$^{211}_{84}Po$	Actinium C'	0.52s	7.45 (99%)	---	0.570 (0.5%) 0.90 (0.5%)
$^{207}_{81}Tl$	Actinium C"	4.79m	---	1.44 (99.8%)	0.897 (0.16%)
$^{207}_{82}Pb$	Actinium D	Stable	---	---	---

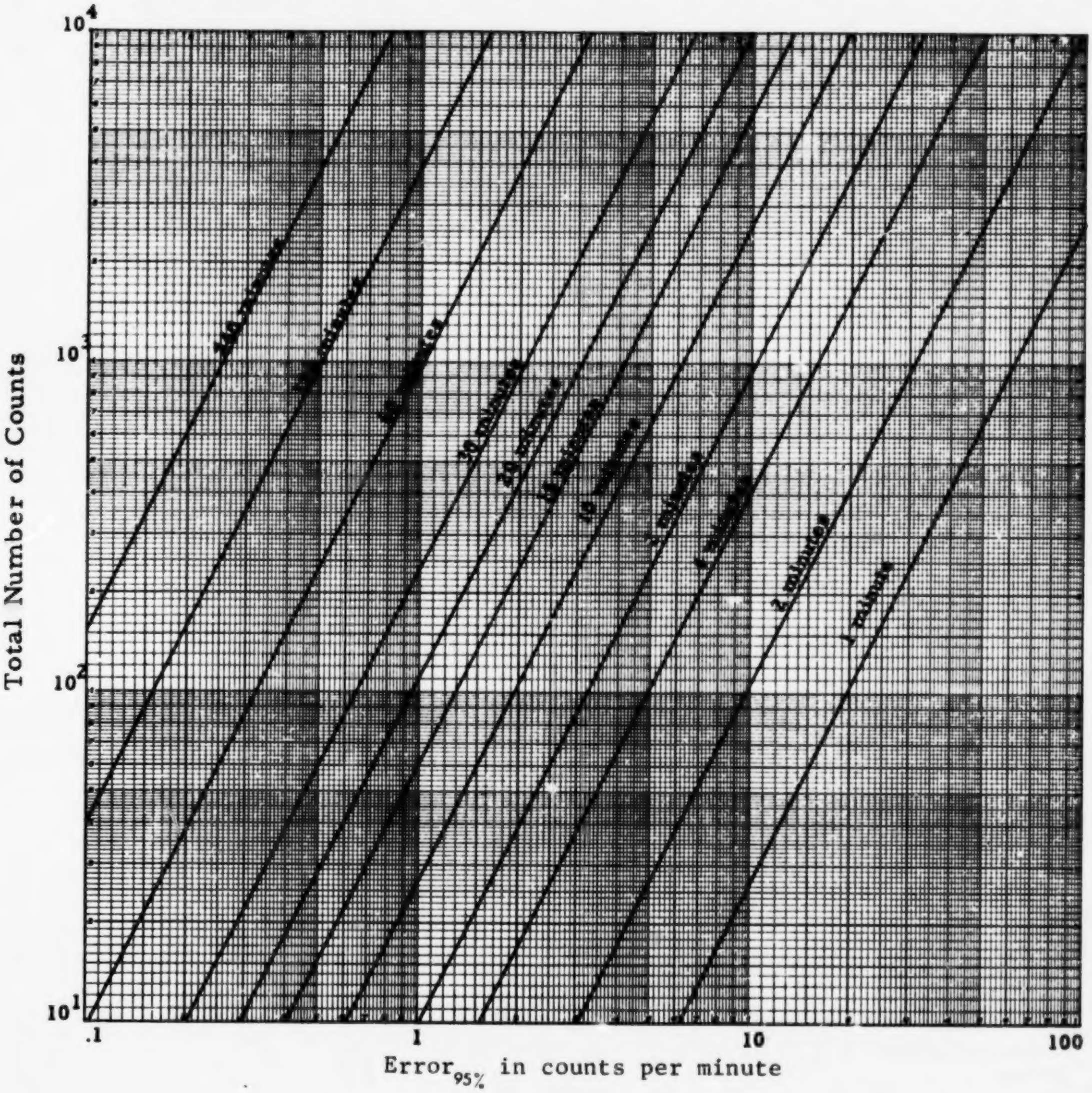
*This expression describes the mass number of any member in this series, where n is an integer.
Example: $^{207}_{82}Pb$ (4n + 3)......4(51) + 3 = 207

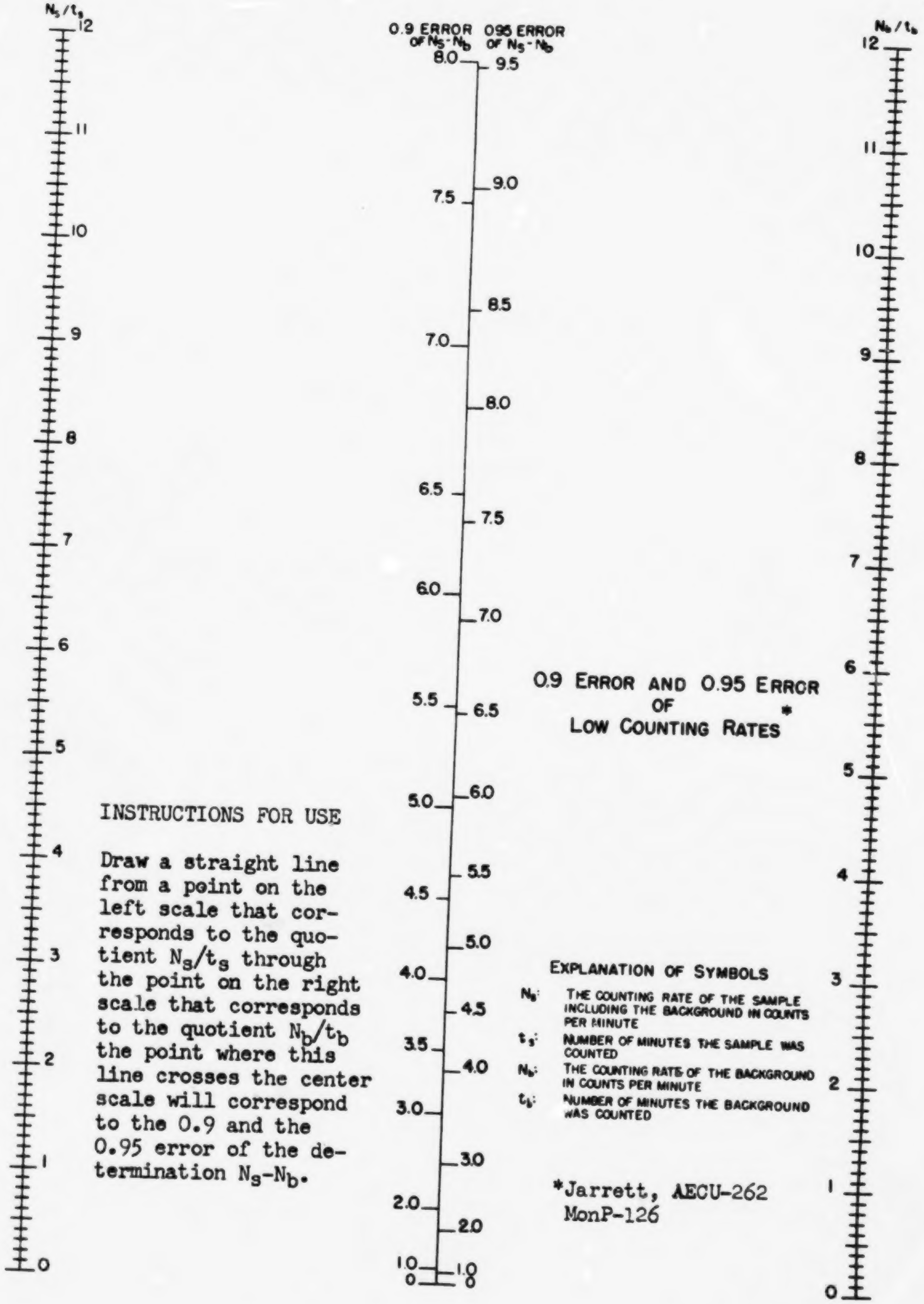
†Intensities refer to percentage of disintegrations of the nuclide itself, not to original parent of series.

‡Complex energy peak which would be incompletely resolved by instruments of moderately low resolving power such as scintillators.

Data taken from: Table of Isotopes and USNRDL-TR-802.

ERROR IN COUNTS PER MINUTE AS A FUNCTION OF TOTAL COUNT AND LENGTH OF COUNT. (95% CONFIDENCE LEVEL)




Ns/ts
12
11
10
9
8
7
6
5
4
3
2
1
0
0.9 ERROR OF Ns-Nb
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.0
1.0
0
0.95 ERROR OF Ns-Nb
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.0
2.0
1.0
0
Nb/tb
12
11
10
9
8
7
6
5
4
3
2
1
0

0.9 ERROR AND 0.95 ERROR OF LOW COUNTING RATES*

INSTRUCTIONS FOR USE

Draw a straight line from a point on the left scale that corresponds to the quotient N_s/t_s through the point on the right scale that corresponds to the quotient N_b/t_b the point where this line crosses the center scale will correspond to the 0.9 and the 0.95 error of the determination N_s-N_b.

EXPLANATION OF SYMBOLS

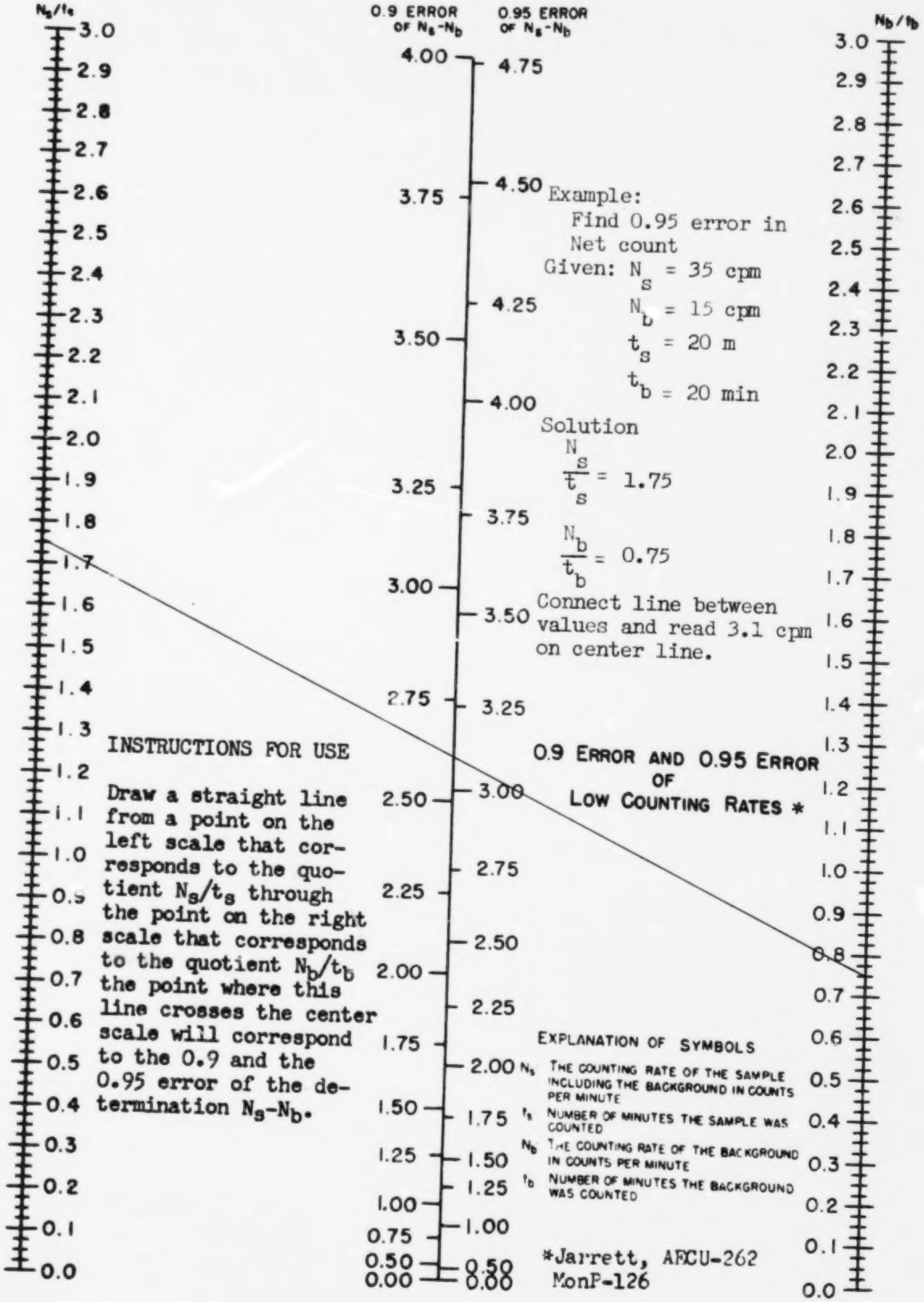
N_s: THE COUNTING RATE OF THE SAMPLE INCLUDING THE BACKGROUND IN COUNTS PER MINUTE

t_s: NUMBER OF MINUTES THE SAMPLE WAS COUNTED

N_b: THE COUNTING RATE OF THE BACKGROUND IN COUNTS PER MINUTE

t_b: NUMBER OF MINUTES THE BACKGROUND WAS COUNTED

*Jarrett, AECU-262
MonP-126



0.9 ERROR AND 0.95 ERROR OF LOW COUNTING RATES *

Example:
Find 0.95 error in Net count

Given: $N_s = 35$ cpm
$N_b = 15$ cpm
$t_s = 20$ m
$t_b = 20$ min

Solution

$$\frac{N_s}{t_s} = 1.75$$

$$\frac{N_b}{t_b} = 0.75$$

Connect line between values and read 3.1 cpm on center line.

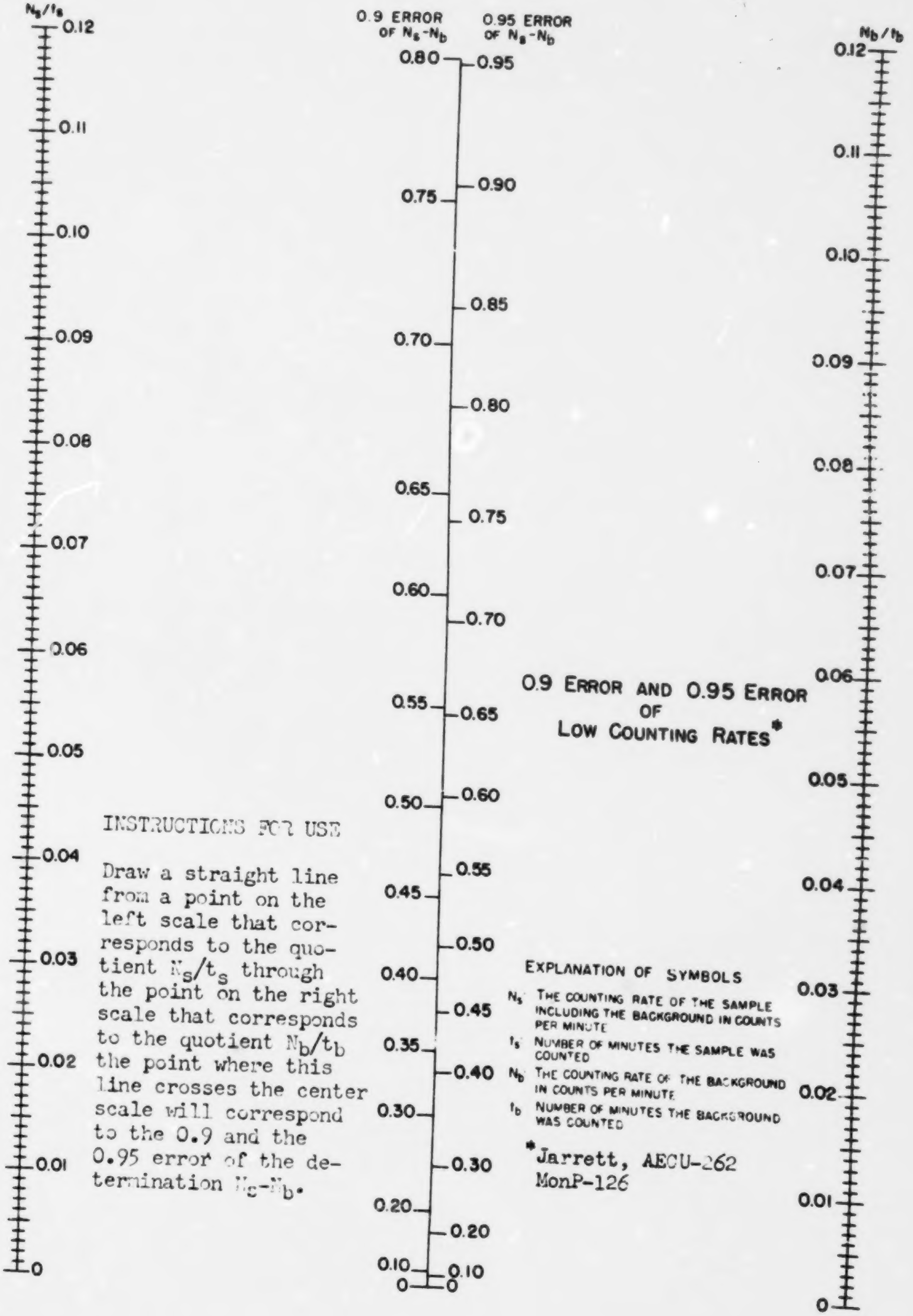
INSTRUCTIONS FOR USE

Draw a straight line from a point on the left scale that corresponds to the quotient N_s/t_s through the point on the right scale that corresponds to the quotient N_b/t_b the point where this line crosses the center scale will correspond to the 0.9 and the 0.95 error of the determination N_s-N_b.

EXPLANATION OF SYMBOLS

N_s THE COUNTING RATE OF THE SAMPLE INCLUDING THE BACKGROUND IN COUNTS PER MINUTE
t_s NUMBER OF MINUTES THE SAMPLE WAS COUNTED
N_b THE COUNTING RATE OF THE BACKGROUND IN COUNTS PER MINUTE
t_b NUMBER OF MINUTES THE BACKGROUND WAS COUNTED

*Jarrett, AECU-262
MonP-126



0.9 ERROR AND 0.95 ERROR OF LOW COUNTING RATES*

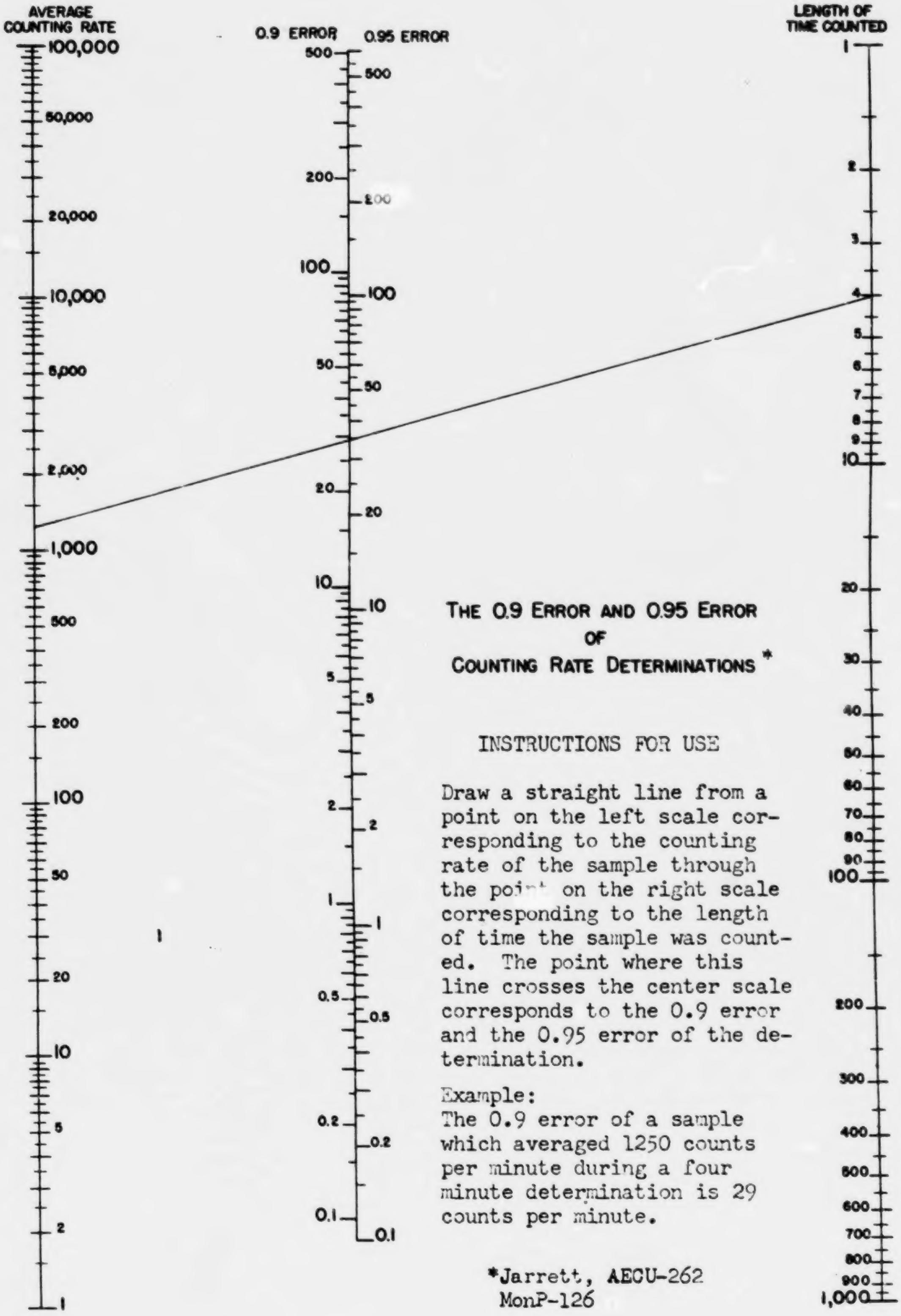
INSTRUCTIONS FOR USE

Draw a straight line from a point on the left scale that corresponds to the quotient N_s/t_s through the point on the right scale that corresponds to the quotient N_b/t_b the point where this line crosses the center scale will correspond to the 0.9 and the 0.95 error of the determination N_s-N_b.

EXPLANATION OF SYMBOLS

N_s THE COUNTING RATE OF THE SAMPLE INCLUDING THE BACKGROUND IN COUNTS PER MINUTE
t_s NUMBER OF MINUTES THE SAMPLE WAS COUNTED
N_b THE COUNTING RATE OF THE BACKGROUND IN COUNTS PER MINUTE
t_b NUMBER OF MINUTES THE BACKGROUND WAS COUNTED

*Jarrett, AECU-262
MonP-126



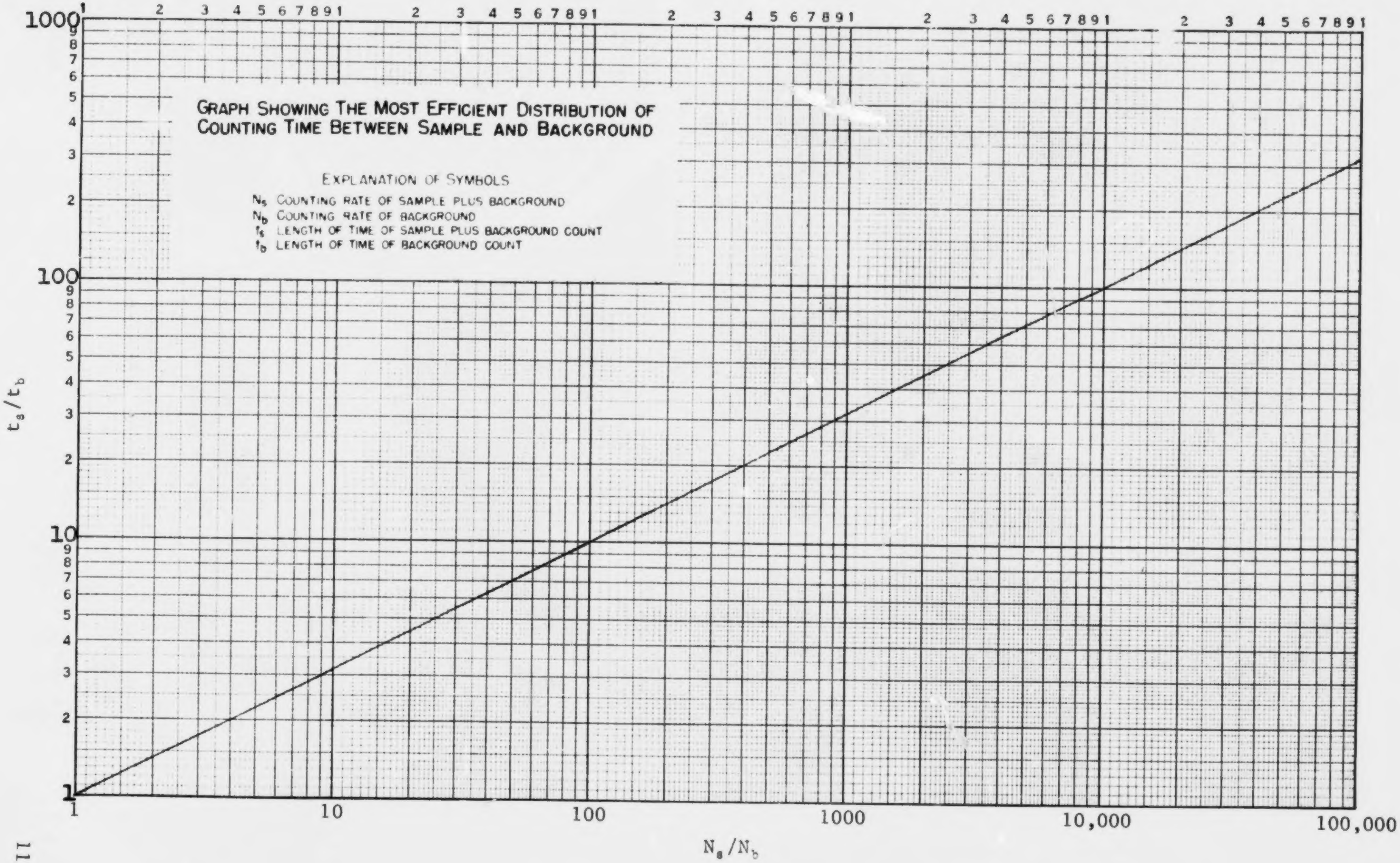
THE 0.9 ERROR AND 0.95 ERROR OF COUNTING RATE DETERMINATIONS *

INSTRUCTIONS FOR USE

Draw a straight line from a point on the left scale corresponding to the counting rate of the sample through the point on the right scale corresponding to the length of time the sample was counted. The point where this line crosses the center scale corresponds to the 0.9 error and the 0.95 error of the determination.

Example:
The 0.9 error of a sample which averaged 1250 counts per minute during a four minute determination is 29 counts per minute.

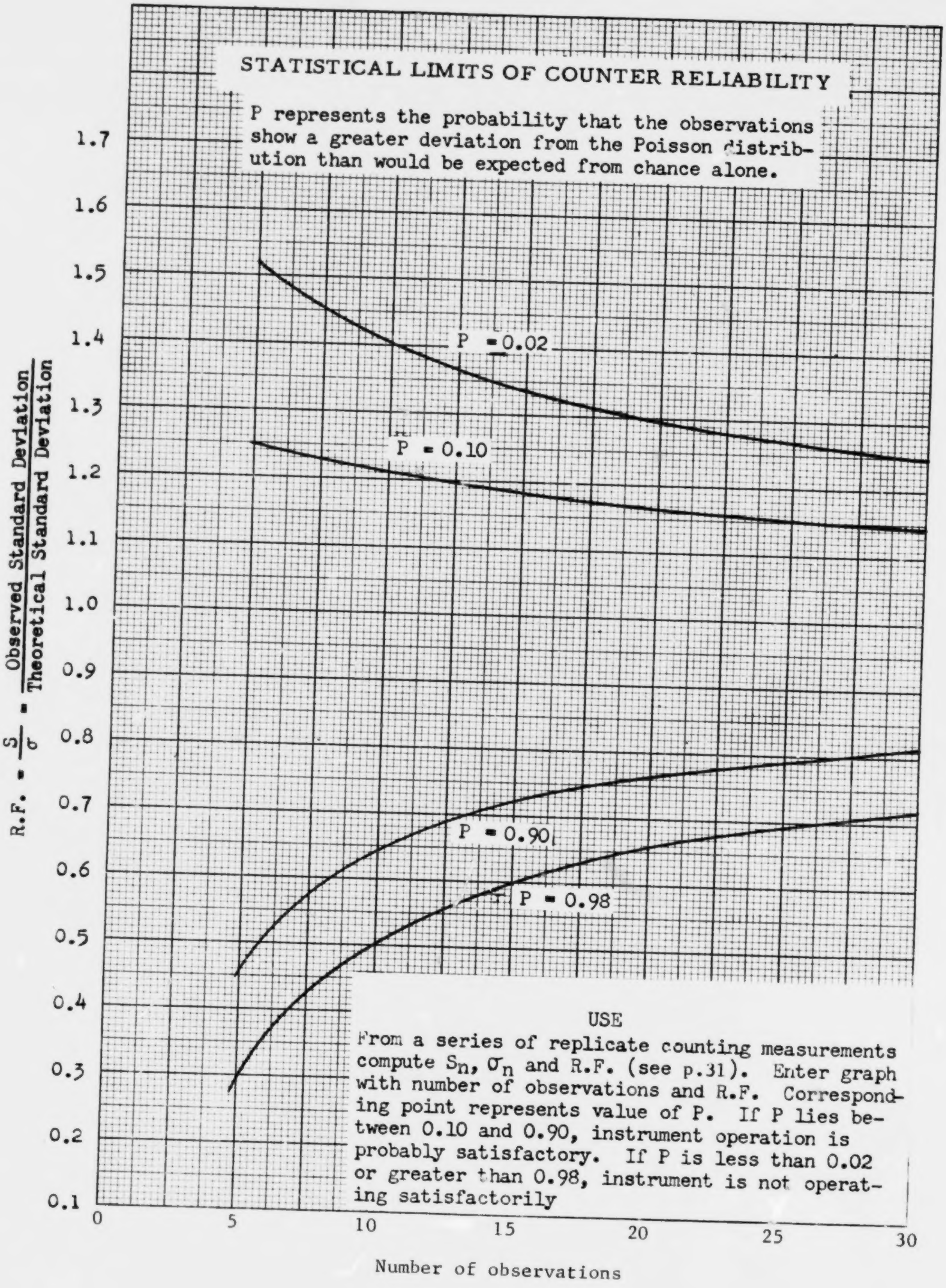
*Jarrett, AECU-262
MonP-126



GRAPH SHOWING THE MOST EFFICIENT DISTRIBUTION OF COUNTING TIME BETWEEN SAMPLE AND BACKGROUND

EXPLANATION OF SYMBOLS

N_s COUNTING RATE OF SAMPLE PLUS BACKGROUND
N_b COUNTING RATE OF BACKGROUND
t_s LENGTH OF TIME OF SAMPLE PLUS BACKGROUND COUNT
t_b LENGTH OF TIME OF BACKGROUND COUNT



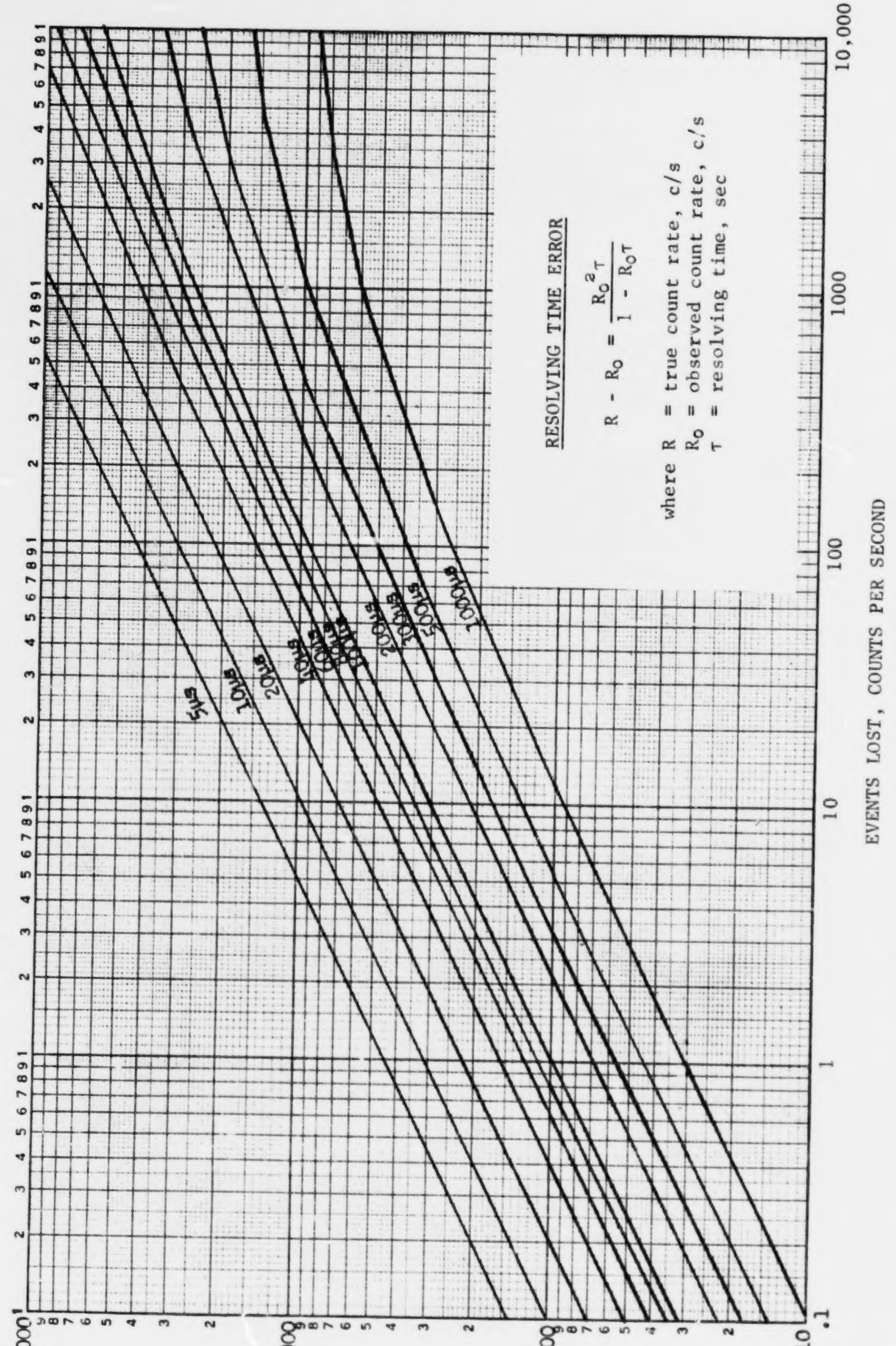
STATISTICAL LIMITS OF COUNTER RELIABILITY

P represents the probability that the observations show a greater deviation from the Poisson distribution than would be expected from chance alone.

USE

From a series of replicate counting measurements compute S_n, σ_n and R.F. (see p.31). Enter graph with number of observations and R.F. Corresponding point represents value of P. If P lies between 0.10 and 0.90, instrument operation is probably satisfactory. If P is less than 0.02 or greater than 0.98, instrument is not operating satisfactorily

R.F. = S/σ = Observed Standard Deviation / Theoretical Standard Deviation
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
P = 0.02
P = 0.10
P = 0.90
P = 0.98
0
5
10
15
20
25
30
Number of observations

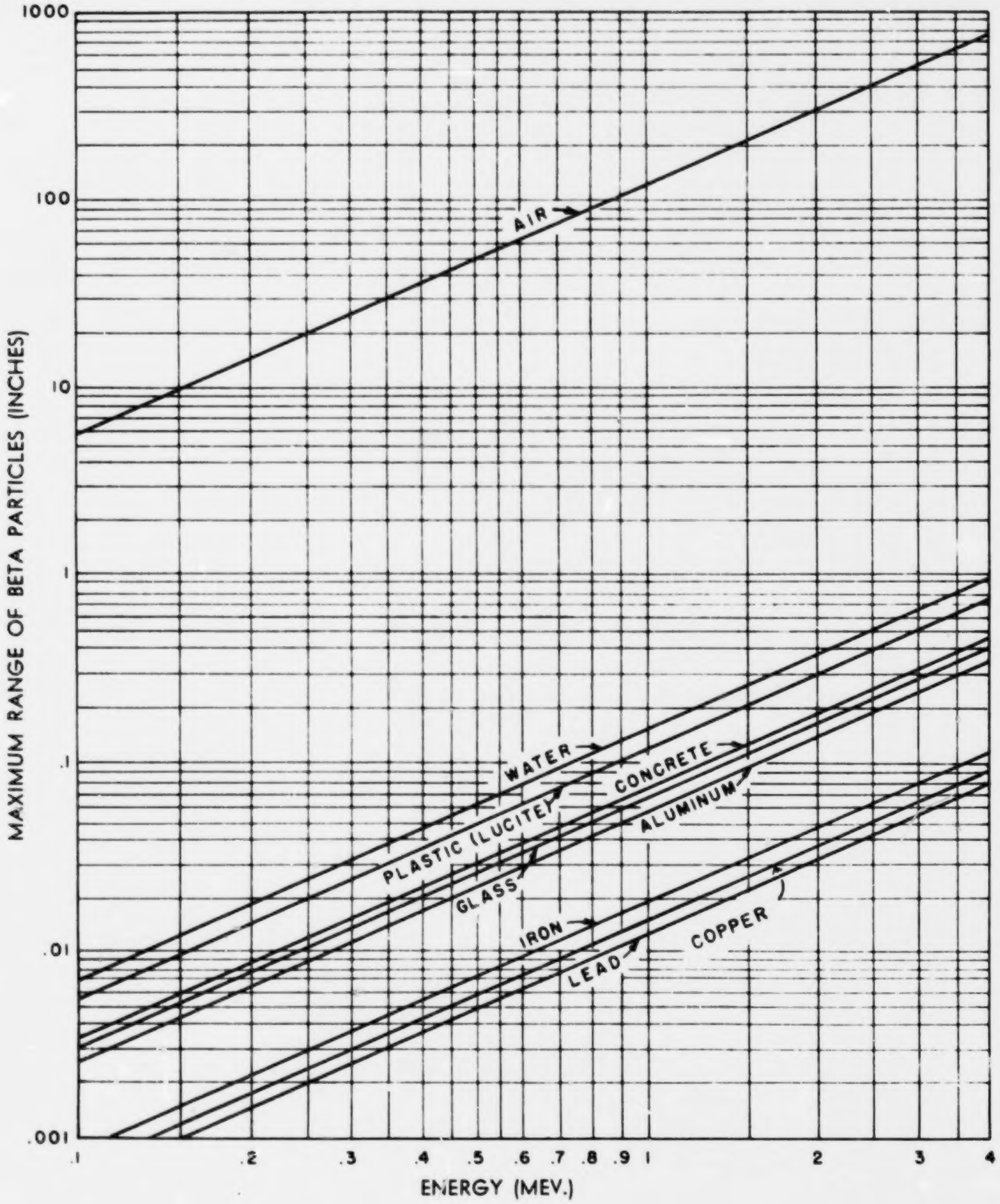


RESOLVING TIME ERROR

$$R - R_o = \frac{R_o^2 \tau}{1 - R_o \tau}$$

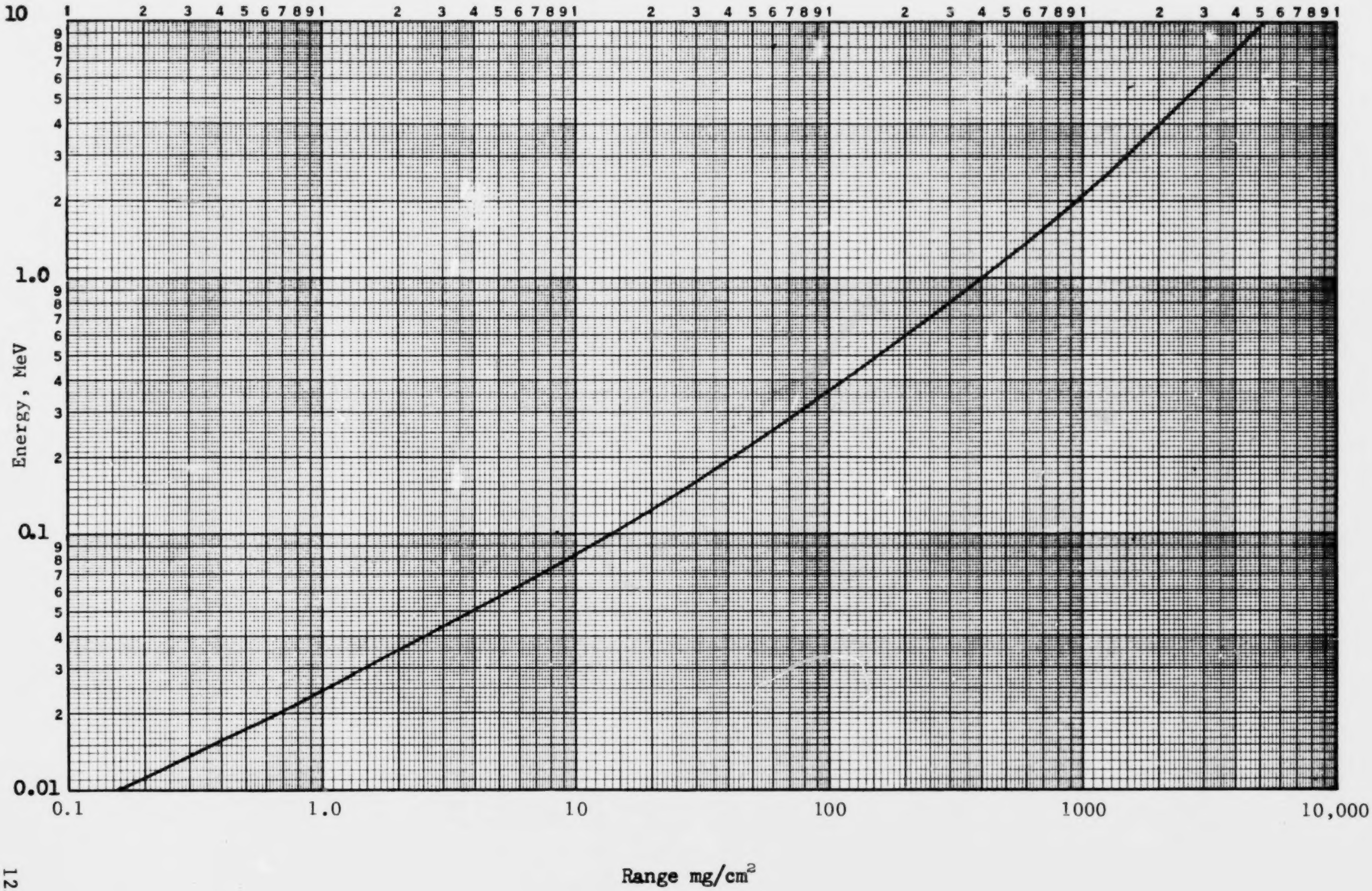
where R = true count rate, c/s
R_o = observed count rate, c/s
τ = resolving time, sec

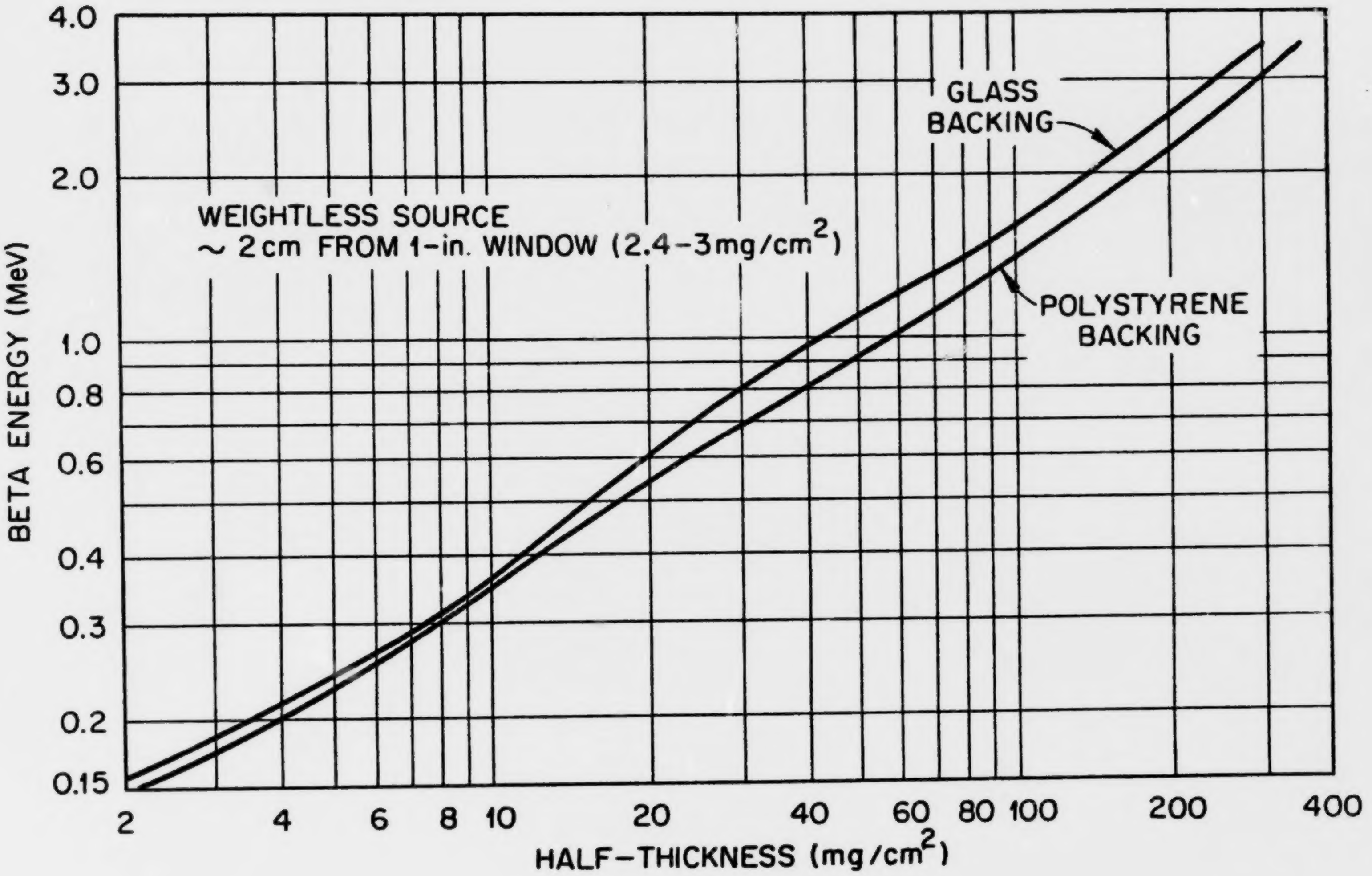
PENETRATION ABILITY OF BETA RADIATION



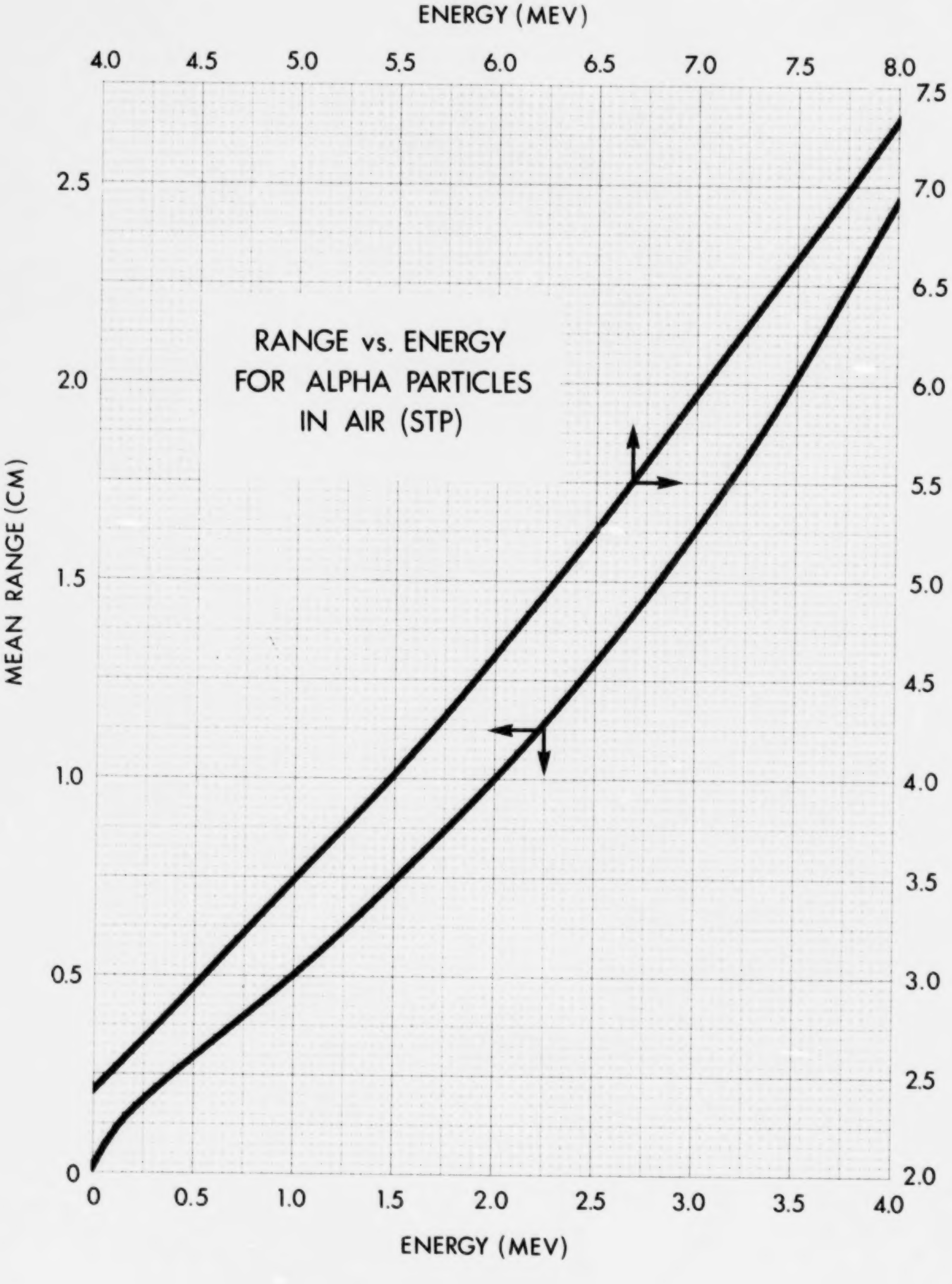
The maximum range of beta particles as a function of energy in the various materials indicated. (From SRI Report No. 361, "The Industrial Uses of Radioactive Fission Products". With permission of the Stanford Research Institute and the U. S. Atomic Energy Commission.)

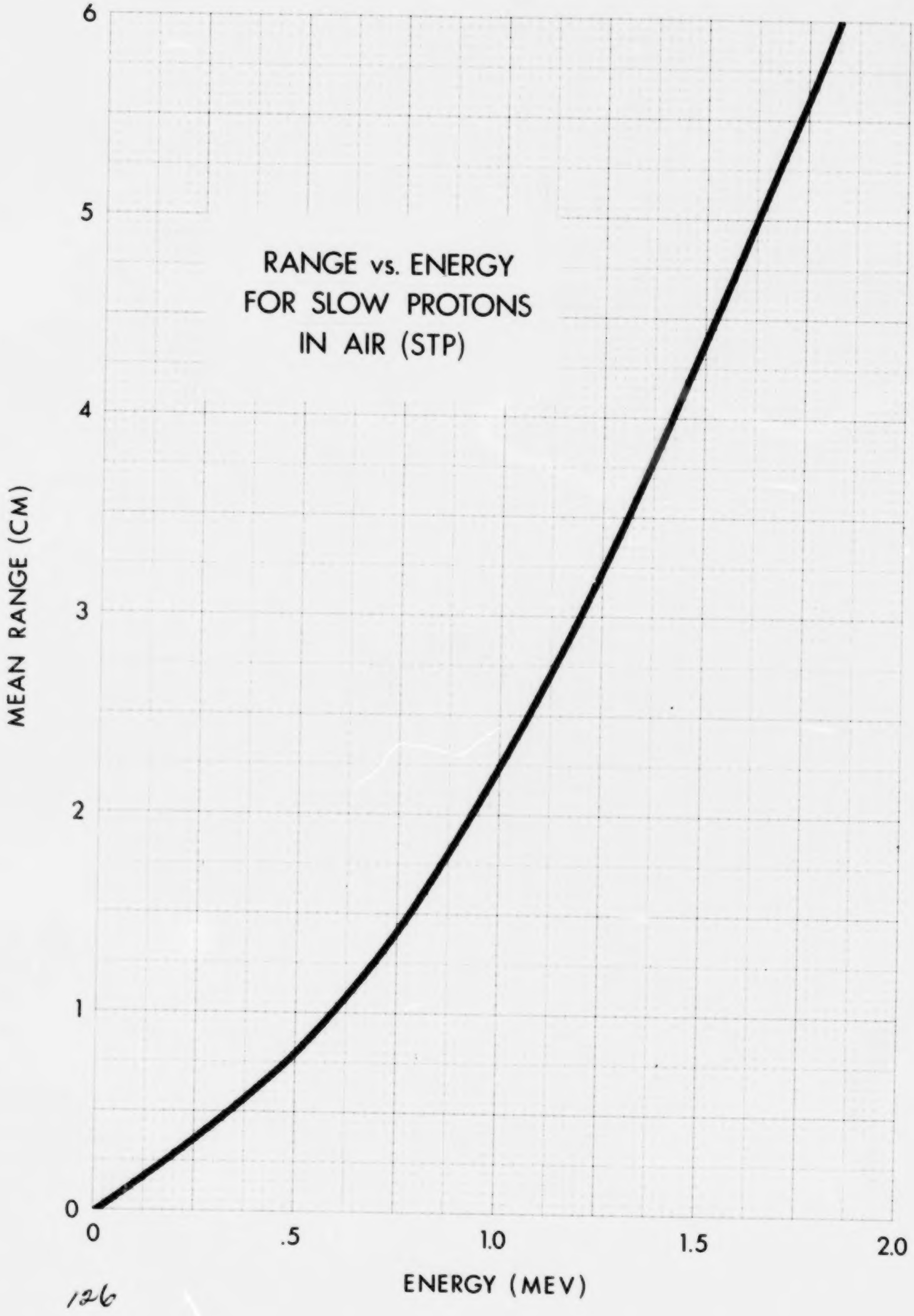
BETA PARTICLE
RANGE ENERGY CURVE





Beta Radiation Initial Half-Thickness in Aluminum vs. Maximum Energy


ENERGY (MEV)
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
RANGE vs. ENERGY
FOR ALPHA PARTICLES
IN AIR (STP)
MEAN RANGE (CM)
0
0.5
1.0
1.5
2.0
2.5
MEAN RANGE (CM)
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
ENERGY (MEV)

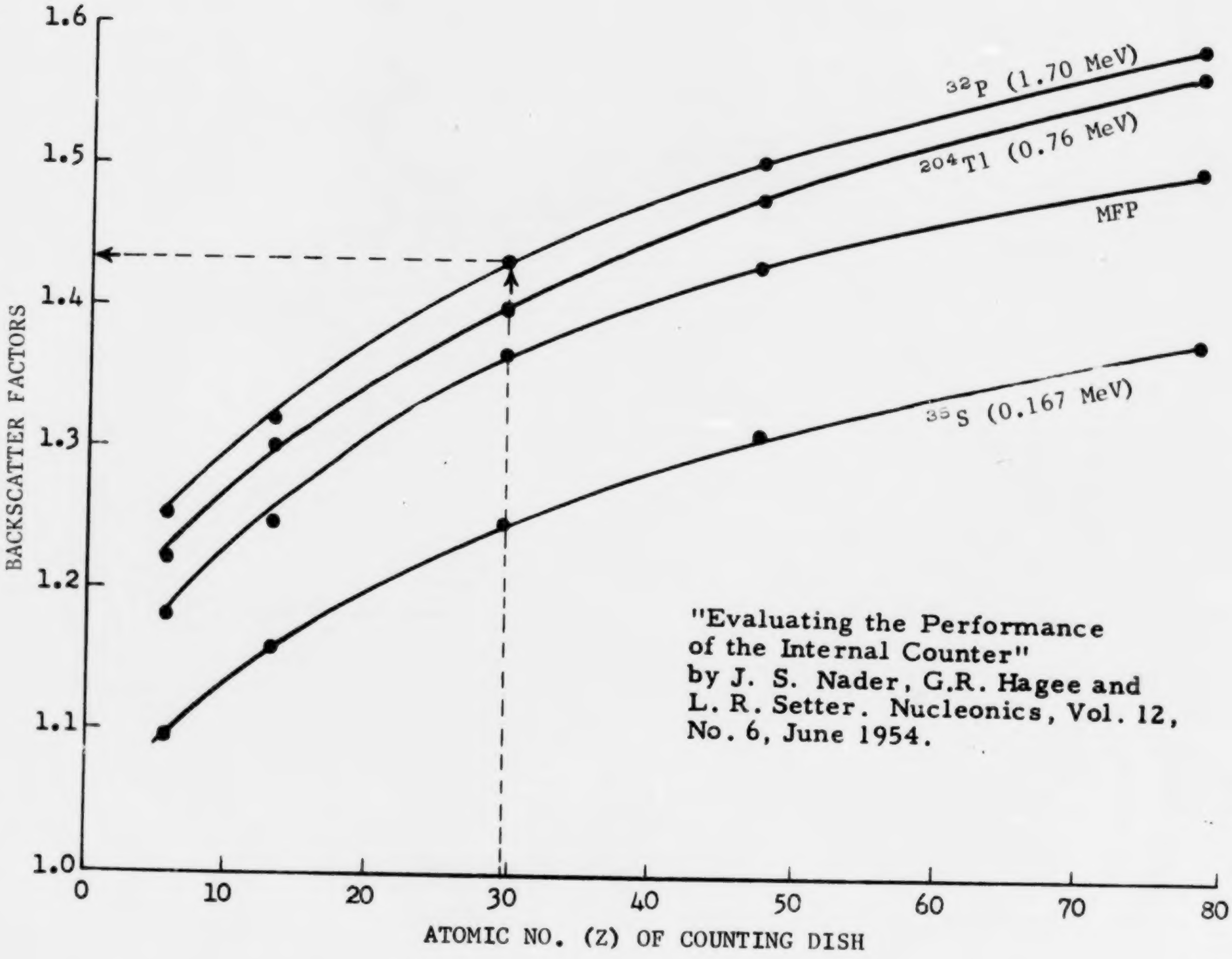

RANGE vs. ENERGY
FOR SLOW PROTONS
IN AIR (STP)
MEAN RANGE (CM)
0
1
2
3
4
5
6
ENERGY (MEV)
0
.5
1.0
1.5
2.0

DETERMINING COUNTING EFFICIENCY FOR INTERNAL PROPORTIONAL COUNTERS

Since internal proportional counters do not detect all beta rays emitted by a sample, it is necessary to divide the net counting rate by an appropriate efficiency correction decimal to determine the total beta emission. This efficiency (E), is the product of three factors--geometry (G), backscatter (B), and self-absorption, generally expressed in terms of a transmission factor (T): $E = G \times B \times T$.

GEOMETRY FACTOR (G)—Not all radiation from a sample is emitted in the direction of the detector. The geometry factor accounts for the fraction emitted in the proper direction. For internal proportional counters with hemispherical chambers, this factor is 0.50.

BACKSCATTER FACTOR (B)—The backscattering of beta rays is a function of their energy and the atomic number (Z) of the counting dish. The following curves may be conveniently used for estimating this factor. To illustrate their use, consider a ^{32}P sample in a copper counting dish (Z = 29). From the appropriate value on the abscissa, draw a vertical line until it intersects the curve for ^{32}P. A horizontal line projected from the point of intersection to the ordinate reveals the resultant factor to be about 1.43.



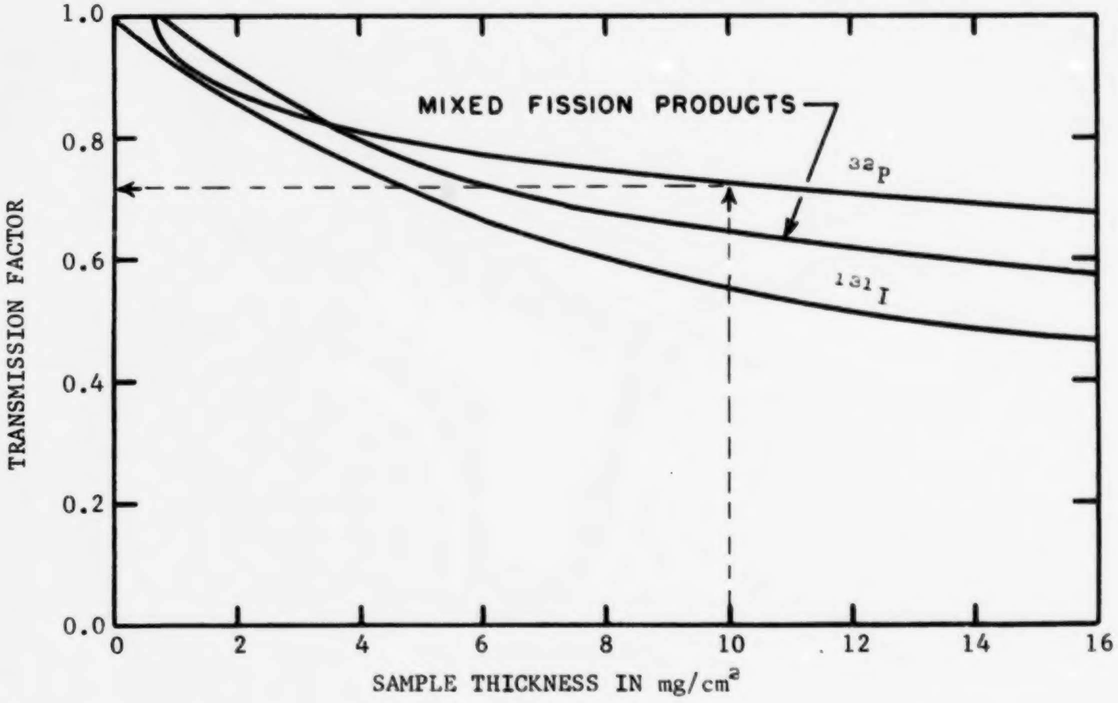
"Evaluating the Performance of the Internal Counter" by J. S. Nader, G.R. Hagee and L. R. Setter. Nucleonics, Vol. 12, No. 6, June 1954.

SELF-ABSORPTION OR TRANSMISSION FACTOR (T)—A fraction of the beta particles emitted by a sample may be absorbed within the sample itself. This loss, which increases with sample thickness, is known as self-absorption. For counting purposes, it may be conveniently expressed in terms of a transmission factor, the fraction of the emitted beta particles not absorbed within a sample.

The transmission factor (T) may be estimated using the curves given below. If, for example, a sample containing ^{32}P weighs 200 milligrams and is evenly distributed on a 2-inch diameter dish, then the average sample thickness can be calculated to be 10 mg/cm^2. To estimate the factor, draw a vertical line from the appropriate value on the abscissa until it intersects the curve for ^{32}P. A horizontal line projected from the point of intersection to the ordinate reveals the resultant factor to be about 0.73.

OVERALL COUNTING EFFICIENCY (E)—The efficiency correction decimal fraction for the previous example, in which a sample containing ^{32}P was counted, would be: E = 0.50 x 1.43 x 0.73 = 0.52.

If the net sample counting rate was 1,000 counts per minute, the disintegration rate could be calculated to be: dpm = net cpm ÷ E = 1,000 cpm ÷ 0.52 = 1,920 dpm.



Data on this page obtained from: "Radioactivity Assay of Water and Industrial Wastes with Internal Proportional Counter," by L. R. Setter, A. S. Goldin, and J. S. Nader, Analytical Chemistry, Vol. 26, p. 1305, Aug. 1954.

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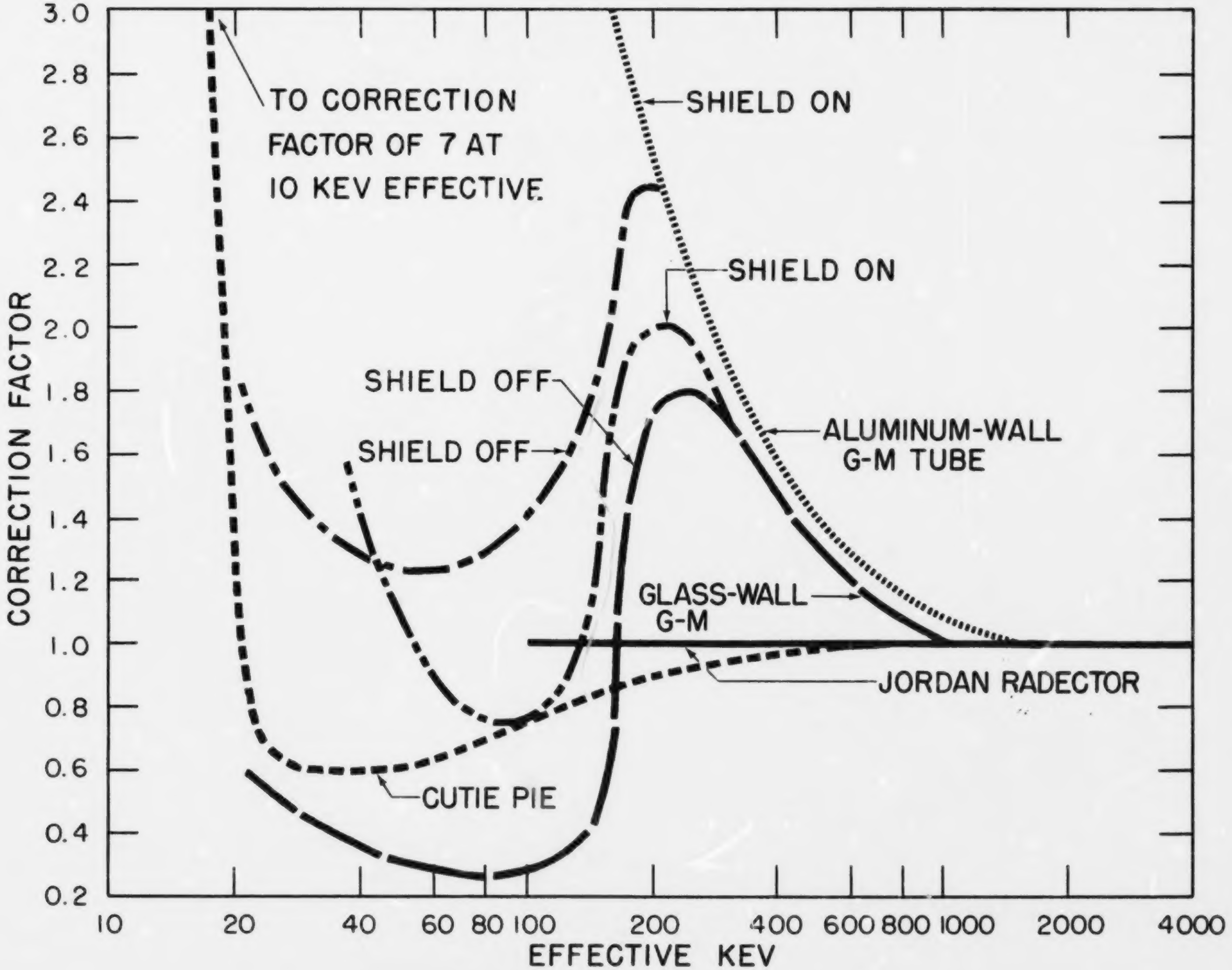
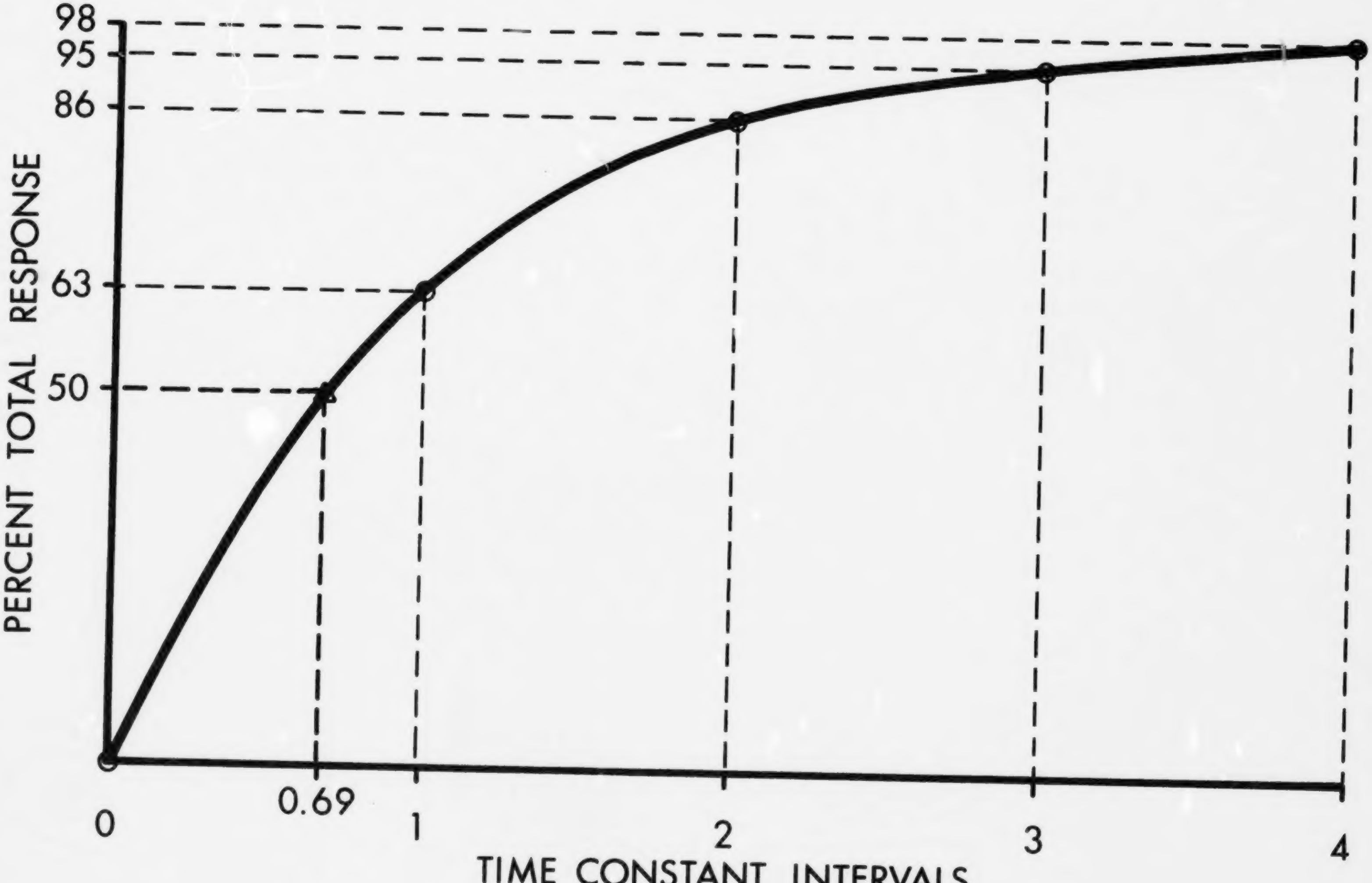


ENERGY DEPENDENCE CORRECTION FACTORS FOR MONITORING INSTRUMENTS

LA - 1835 (3rd edit.)

RESPONSE vs TIME



GAMMA RADIATION LEVELS FOR ONE CURIE OF SOME RADIONUCLIDES*

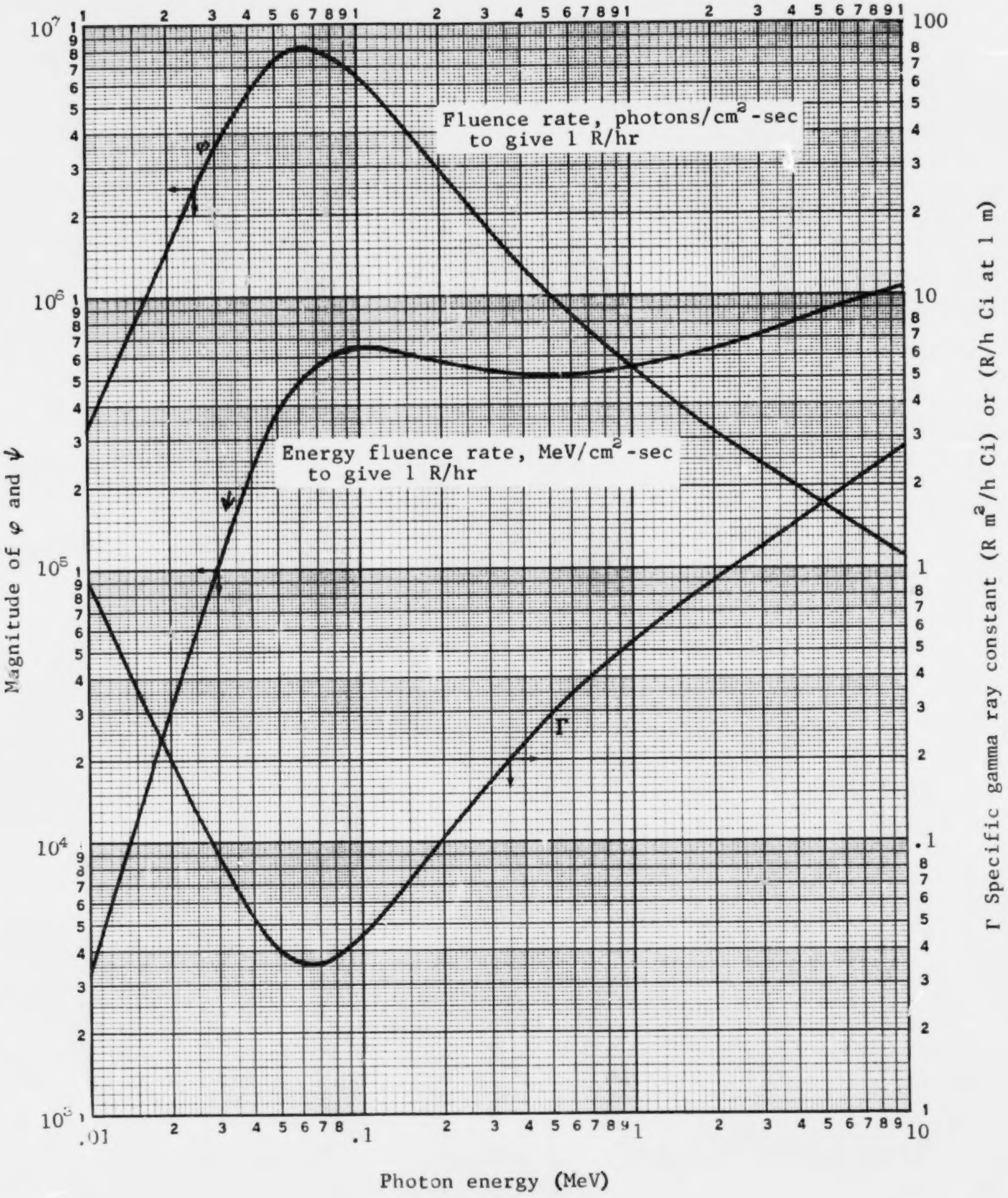
Nuclide	Γ†	Nuclide	Γ†	Nuclide	Γ†
Actinium-227	~2.2	Gold-198	2.3	Potassium-43	5.6
Antimony-122	2.4	Gold-199	~0.9	Radium-226	8.25
Antimony-124	9.8	Hafnium-175	~2.1	Radium-228	~5.1
Antimony-125	~2.7	Hafnium-181	~3.1	Rhenium-186	~0.2
Arsenic-72	10.1	Indium-114m	~0.2	Rubidium-86	0.5
Arsenic-74	4.4	Iodine-124	7.2	Ruthenium-106	1.7
Arsenic-76	2.4	Iodine-125	~0.7	Scandium-46	10.9
Barium-131	~3.0	Iodine-126	2.5	Scandium-47	0.56
Barium-133	~2.4	Iodine-130	12.2	Selenium-75	2.0
Barium-140	12.4	Iodine-131	2.2	Silver-110m	14.3
Beryllium-7	~0.3	Iodine-132	11.8	Silver-111	~0.2
Bromine-82	14.6	Iridium-192	4.8	Sodium-22	12.0
Cadmium-115m	~0.2	Iridium-194	1.5	Sodium-24	18.4
Calcium-47	5.7	Iron-59	6.4	Strontium-85	3.0
Carbon-11‡	5.9	Krypton-85	~0.04	Tantalum-182	6.8
Cerium-141	0.35	Lanthanum-140	11.3	Tellurium-121‡	3.3
Cerium-144	~0.4	Lutecium-177	0.09	Tellurium-132	2.2
Cesium-134	8.7	Magnesium-28	15.7	Thulium-170	0.025
Cesium-137	3.3	Manganese-52	18.6	Tin-113	~1.7
Chlorine-38‡	8.8	Manganese-54	4.7	Tungsten-185	~0.5
Chromium-51	0.16	Manganese-56	8.3	Tungsten-187	3.0
Cobalt-56	17.6	Mercury-197	~0.4	Uranium-234	~0.1
Cobalt-57	0.9	Mercury-203	1.3	Vanadium-48	15.6
Cobalt-58	5.5	Molybdenum-99	~1.8	Xenon-133	0.1
Cobalt-60	13.2	Neodymium-147	0.8	Ytterbium-175	0.4
Copper-64	1.2	Nickel-65	~3.1	Yttrium-88	14.1
Europium-152	5.8	Niobium-95	4.2	Yttrium-91	0.01
Europium-154	~6.2	Osmium-191	~0.6	Zinc-65	2.7
Europium-155	~0.3	Palladium-109	0.03	Zirconium-95	4.1
Gallium-67	~1.1	Platinum-197	~0.5		
Gallium-72	11.6	Potassium-42	1.4		

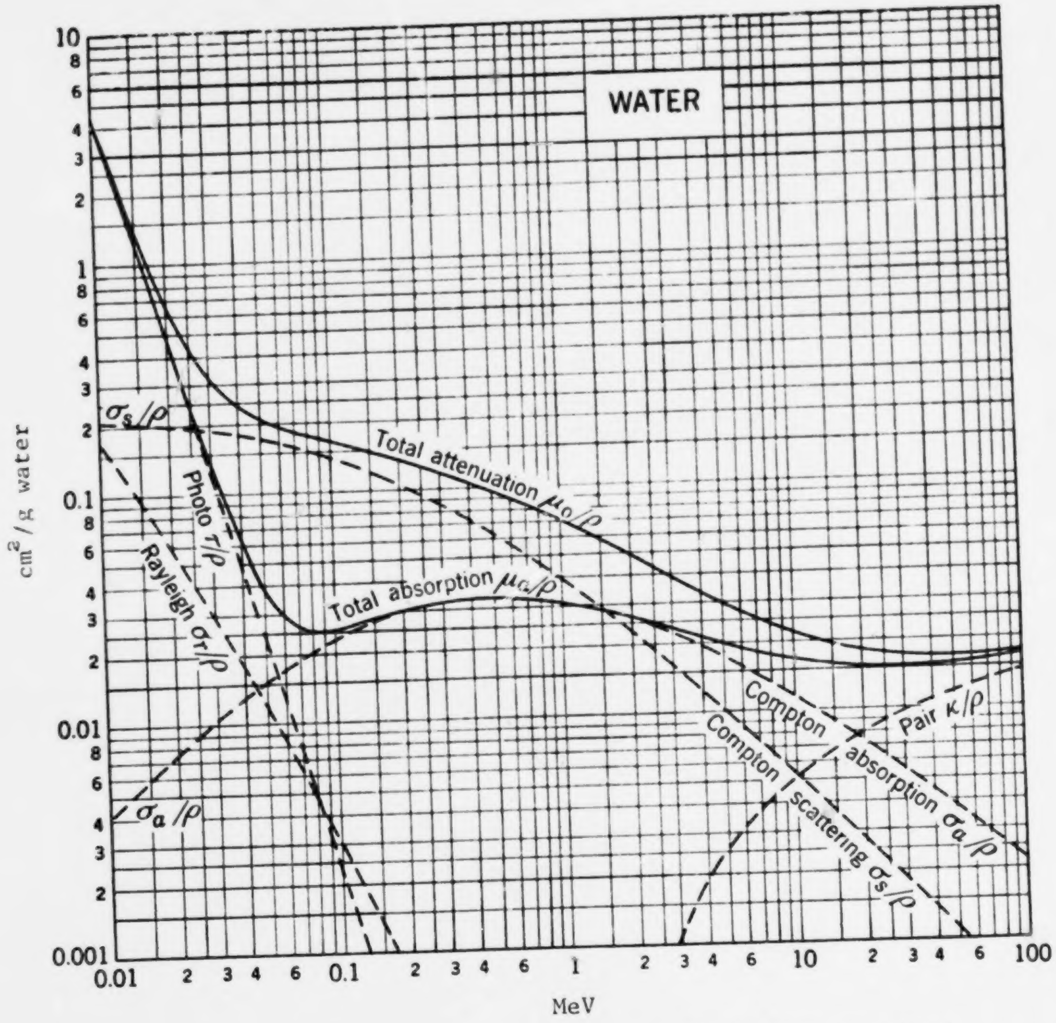
---

* Jaeger, R. G., et al., Engineering Compendium on Radiation Shielding, Vol. 1, (New York: Springer-Verlag, 1968), pp. 21-30.

† Γ = R-cm^2/hr-mCi or $\Gamma/10$ = R/hr at 1 m/Ci

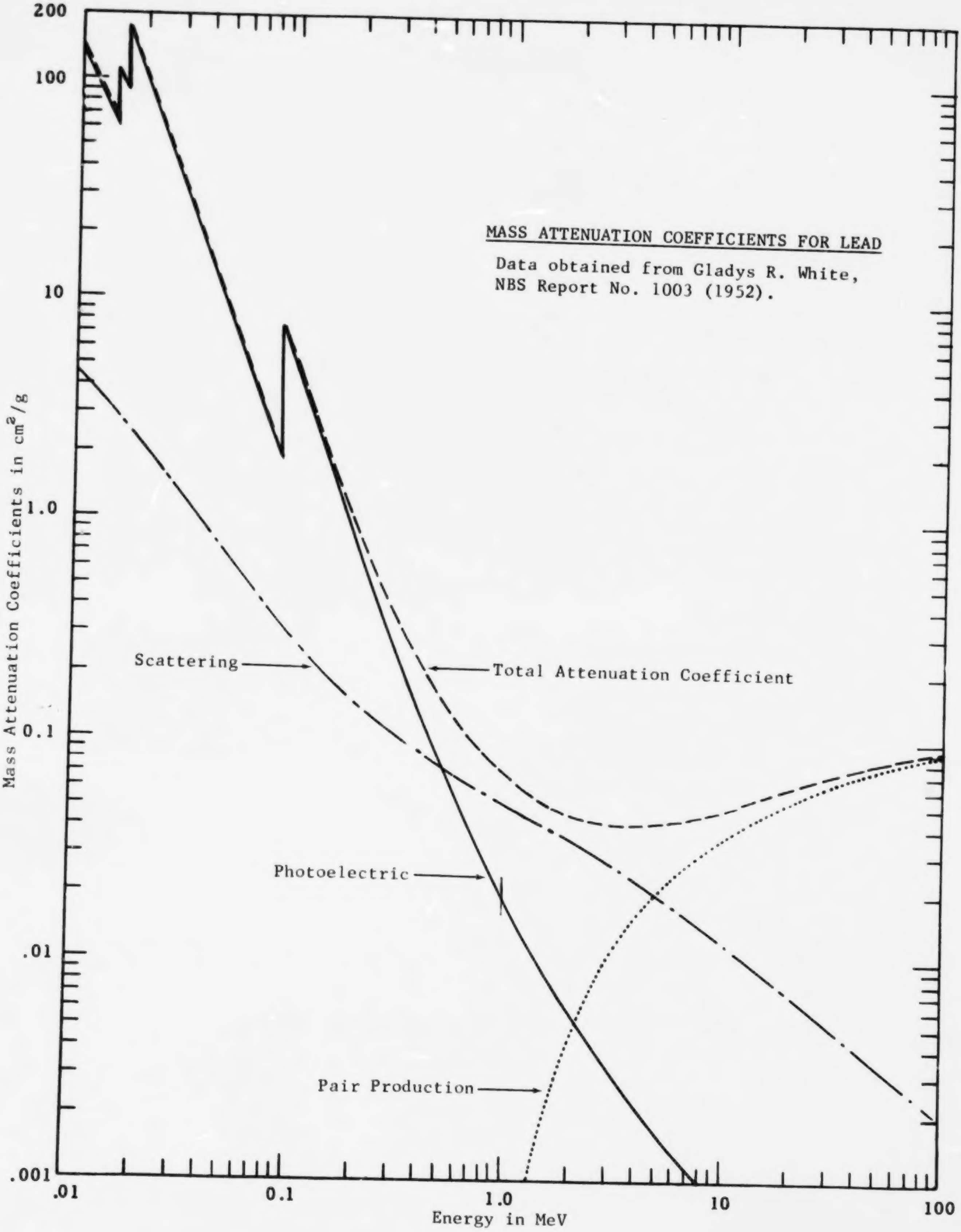
‡ A Manual of Radioactivity Procedures (National Bureau of Standards Handbook No. 80 [Washington, D.C.: Supt. of Docs., U.S. Government Printing Office, Nov. 1961)], Appendix A, pp. 137-140.


Fluence rate, photons/cm^2-sec to give 1 R/hr
Energy fluence rate, MeV/cm^2-sec to give 1 R/hr
φ
ψ
Γ
Magnitude of φ and ψ
Γ Specific gamma ray constant (R m^2/h Ci) or (R/h Ci at 1 m)
Photon energy (MeV)
10^7
10^6
10^5
10^4
10^3
100
10
1
.1
.01
.1
1
10



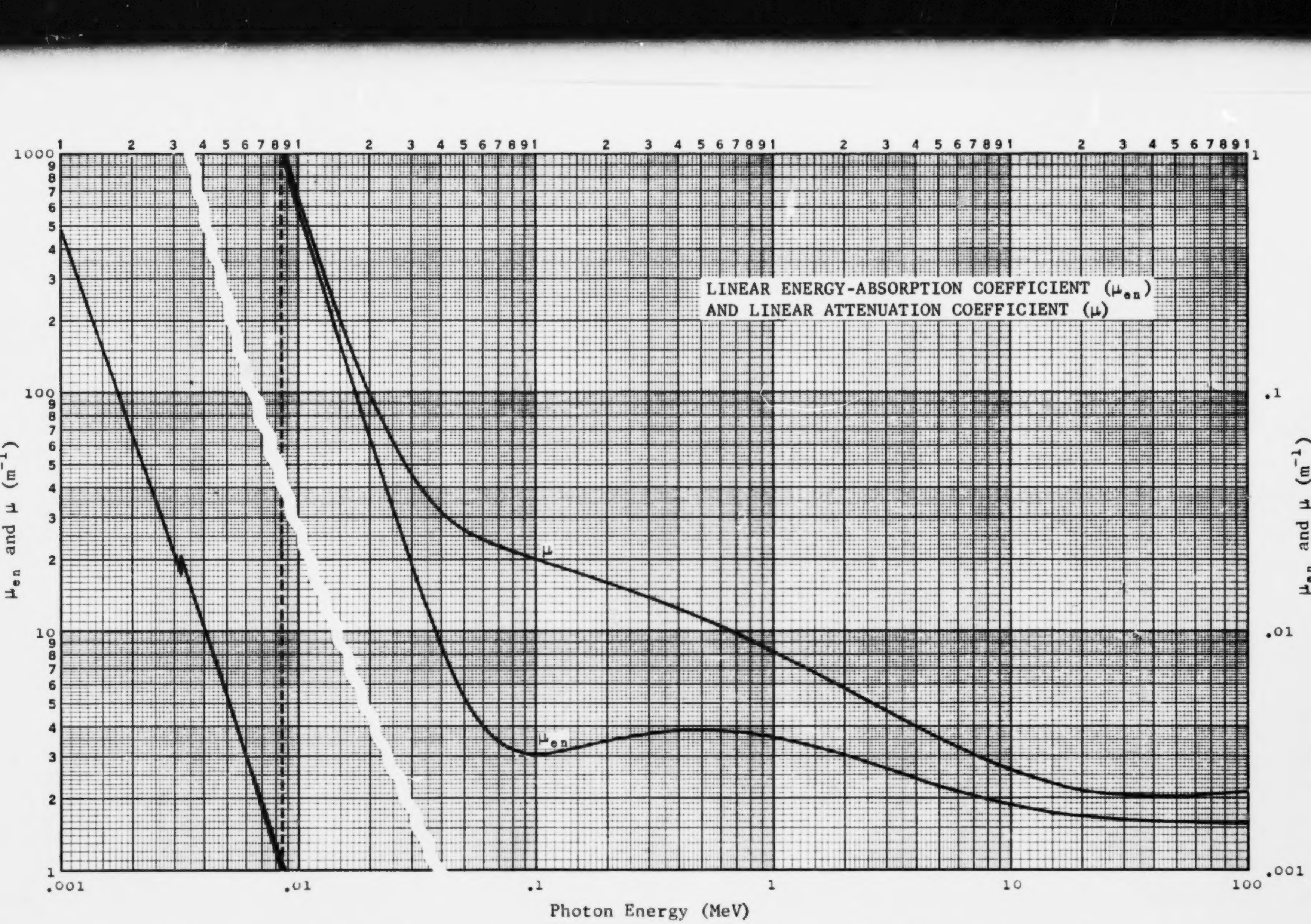
MASS ATTENUATION COEFFICIENTS FOR GAMMA RAYS IN WATER

From The Atomic Nucleus, by R. D. Evans,
Copyright 1955, by permission of McGraw-
Hill Book Co., Inc.

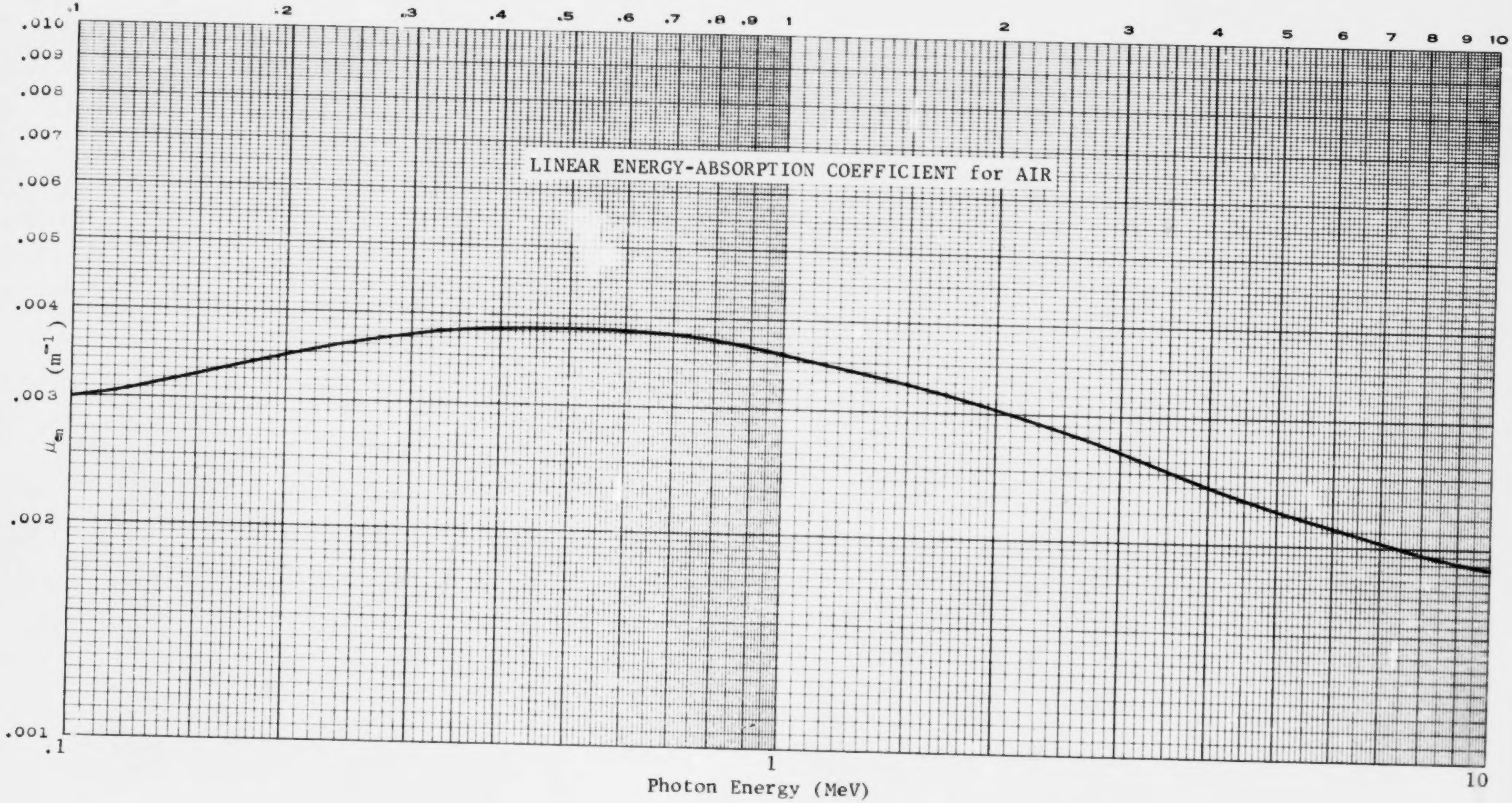


MASS ATTENUATION COEFFICIENTS FOR LEAD

Data obtained from Gladys R. White, NBS Report No. 1003 (1952).



Linear energy-absorption coefficient (μ_{en}) and linear attenuation coefficient (μ) for air at 0° C. and 760 mm in units of inverse meters as functions of photon energy in MeV. The attenuation coefficients from .003 to 100 MeV were derived from mass attenuation coefficients (with coherent) given in NBS Circular 583, 1957, and its supplement, 1959. The energy-absorption coefficients for .01 to 100 MeV were derived from data published in Engineering Compendium on Radiation Shielding, Vol. 1 (1968), pp. 183 and 184. The μ_{en} for the range .003 to .01 are based on the μ values adjusted for Compton and coherent scattering. The range below .003 is extrapolated and involves an uncertainty of about ± 250 at .001, ± 50 at .0015, and ± 15 at .002.



LINEAR ENERGY-ABSORPTION COEFFICIENT for AIR

MASS ATTENUATION COEFFICIENTS*

Photon Energy	H	Be	B	C	N	O	Na	Mg	Al	Si	P	S
keV												
10	0.385	0.593	1.16	2.28	3.73	5.78	15.5	20.8	26.3	34.2	40.8	51.0
15	.376	.300	0.463	0.787	1.18	1.74	4.58	6.23	7.93	10.3	12.4	15.6
20	.369	.227	.295	.429	0.596	0.826	2.01	2.72	3.41	4.39	5.31	6.66
30	.357	.181	.206	.251	.304	.372	0.705	0.918	1.12	1.41	1.66	2.07
40	.346	.165	.180	.206	.229	.257	.395	.485	0.567	0.696	0.797	0.968
50	.335	.156	.167	.187	.198	.213	.281	.329	.369	.437	.489	.579
60	.326	.150	.159	.176	.182	.191	.228	.258	.280	.322	.350	.404
80	.309	.140	.147	.161	.164	.168	.181	.196	.203	.224	.234	.259
100	.294	.133	.139	.152	.153	.156	.159	.169	.171	.184	.187	.202
150	.265	.119	.124	.135	.135	.136	.134	.140	.138	.145	.144	.151
200	.243	.109	.114	.123	.123	.124	.120	.125	.122	.128	.125	.130
300	.211	.0945	.0984	.107	.107	.107	.103	.106	.104	.108	.106	.109
400	.189	.0847	.0883	.0957	.0954	.0957	.0918	.0949	.0927	.0962	.0936	.0966
500	.173	.0773	.0806	.0872	.0871	.0873	.0836	.0864	.0844	.0875	.0850	.0878
600	.160	.0715	.0745	.0807	.0805	.0808	.0774	.0797	.0780	.0808	.0784	.0810
800	.140	.0629	.0655	.0709	.0708	.0708	.0678	.0701	.0684	.0707	.0688	.0709
MeV												
1.0	.126	.0565	.0589	.0637	.0636	.0637	.0609	.0628	.0613	.0635	.0617	.0638
1.5	.103	.0460	.0479	.0519	.0518	.0518	.0497	.0512	.0500	.0518	.0503	.0518
2.0	.0875	.0394	.0411	.0445	.0445	.0446	.0428	.0442	.0432	.0448	.0436	.0449
3.0	.0691	.0314	.0328	.0357	.0358	.0360	.0349	.0361	.0354	.0368	.0359	.0371
4	.0581	.0266	.0280	.0305	.0307	.0310	.0304	.0316	.0311	.0324	.0317	.0329
5	.0505	.0235	.0248	.0271	.0274	.0278	.0276	.0287	.0284	.0297	.0292	.0304
6	.0450	.0212	.0225	.0247	.0251	.0255	.0256	.0268	.0266	.0279	.0275	.0287
8	.0375	.0182	.0195	.0216	.0221	.0226	.0232	.0244	.0244	.0257	.0255	.0268
10	.0325	.0163	.0175	.0196	.0202	.0209	.0218	.0231	.0231	.0246	.0245	.0258
15	.0254	.0136	.0149	.0170	.0178	.0186	.0202	.0216	.0219	.0234	.0236	.0251
20	.0215	.0122	.0137	.0158	.0167	.0177	.0196	.0212	.0216	.0233	.0235	.0252
30	.0174	.0110	.0125	.0147	.0158	.0170	.0196	.0213	.0219	.0238	.0242	.0261
40	.0154	.0104	.0121	.0144	.0156	.0169	.0199	.0217	.0224	.0245	.0250	.0270
50	.0141	.0102	.0119	.0142	.0156	.0170	.0202	.0222	.0230	.0252	.0257	.0278
60	.0133	.0100	.0118	.0143	.0157	.0172	.0206	.0227	.0235	.0257	.0264	.0286
80	.0124	.00991	.0118	.0144	.0160	.0175	.0213	.0235	.0244	.0267	.0274	.0298
100	.0119	.00992	.0119	.0146	.0163	.0179	.0218	.0241	.0251	.0275	.0283	.0307
150	.0113	.0100	.0122	.0150	.0168	.0186	.0228	.0253	.0263	.0289	.0298	.0324
200	.0112	.0102	.0124	.0153	.0172	.0191	.0235	.0260	.0271	.0299	.0307	.0334
300	.0111	.0104	.0128	.0159	.0178	.0198	.0244	.0270	.0282	.0310	.0319	.0348
400	.0112	.0106	.0130	.0162	.0182	.0202	.0249	.0276	.0288	.0317	.0327	.0356
500	.0113	.0108	.0132	.0164	.0185	.0205	.0252	.0280	.0292	.0322	.0332	.0361
600	.0113	.0109	.0134	.0166	.0187	.0207	.0255	.0283	.0295	.0325	.0335	.0365
800	.0115	.0111	.0136	.0169	.0190	.0210	.0259	.0287	.0300	.0330	.0340	.0370
GeV												
1	.0116	.0112	.0137	.0171	.0192	.0212	.0261	.0290	.0302	.0333	.0344	.0374
1.5	.0117	.0114	.0140	.0173	.0195	.0216	.0265	.0293	.0307	.0338	.0348	.0380
2	.0118	.0115	.0141	.0175	.0196	.0218	.0267	.0296	.0309	.0341	.0351	.0383
3	.0120	.0116	.0143	.0177	.0199	.0220	.0269	.0298	.0312	.0344	.0354	.0386
4	.0120	.0117	.0144	.0178	.0200	.0221	.0270	.0300	.0313	.0345	.0356	.0388
5	.0121	.0118	.0144	.0179	.0200	.0222	.0271	.0301	.0314	.0346	.0357	.0389
6	.0121	.0118	.0145	.0179	.0201	.0222	.0272	.0302	.0315	.0347	.0358	.0390
8	.0122	.0119	.0145	.0180	.0202	.0223	.0272	.0302	.0316	.0348	.0359	.0391
10	.0122	.0119	.0146	.0180	.0202	.0223	.0273	.0303	.0316	.0348	.0359	.0391
15	.0122	.0119	.0146	.0181	.0203	.0224	.0274	.0303	.0317	.0349	.0360	.0392
20	.0123	.0120	.0147	.0181	.0203	.0224	.0274	.0304	.0317	.0350	.0361	.0393
30	.0123	.0120	.0147	.0182	.0203	.0225	.0274	.0304	.0318	.0350	.0361	.0393
40	.0123	.0120	.0147	.0182	.0203	.0225	.0275	.0305	.0318	.0351	.0361	.0394
50	.0123	.0120	.0147	.0182	.0204	.0225	.0275	.0305	.0318	.0351	.0362	.0394
60	.0123	.0120	.0147	.0182	.0204	.0225	.0275	.0305	.0318	.0351	.0362	.0394
80	.0123	.0120	.0147	.0182	.0204	.0225	.0275	.0305	.0318	.0351	.0362	.0394
100	.0123	.0120	.0147	.0182	.0204	.0225	.0275	.0305	.0319	.0351	.0362	.0394

* Coefficients are "Total with Coherent." Unit is cm^2/g .

Source: Photon Cross Sections, Attenuation Coefficients, and Energy Absorption Coefficients From 10 keV to 100 GeV (NSRDS-NBS 29), 1969.

MASS ATTENUATION COEFFICIENTS--Continued

Photon Energy	Ar	K	Ca	Fe	Cu	Mo	Sn	I	W	Pb	U	H_2O
keV												
10	64.5	80.9	96.5	173.	224.	86.2	141.	161.	95.5+	133.+	178.	5.18
15	19.9	25.0	30.1	56.4	74.2	28.2	47.0	55.2	142.	115.+	63.9+	1.58
20	8.53	10.8	13.0	25.5	33.5	81.7*	21.3*	26.0	67.0	85.7	71.0+	0.775
30	2.62	3.30	3.99	8.13	10.9	28.8	41.3	8.67*	23.0	29.7	41.0	.370
40	1.20	1.49	1.78	3.62	4.89	13.3	19.4	22.7	10.7	14.0	19.7	.267
50	0.687	0.843	0.998	1.94	2.62	7.20	10.7	12.6	5.91	7.81	11.1	.227
60	.460	.560	.648	1.20	1.62	4.41	6.53	7.78	3.65*	4.87	6.96	.206
80	.275	.324	.365	0.595	0.772	2.02	3.02	3.65	7.89	2.33*	3.35	.184
100	.204	.233	.256	.370	.461	1.11	1.68	2.00	4.43	5.40	1.91*	.171
150	.143	.158	.168	.196	.223	0.428	0.614	0.714	1.57	1.97	2.56	.151
200	.121	.132	.138	.146	.157	.245	.328	.372	0.777	0.991	1.28	.137
300	.0996	.108	.112	.110	.112	.139	.164	.178	.320	.404	0.509	.119
400	.0878	.0949	.0979	.0940	.0941	.105	.116	.122	.190	.231	.286	.106
500	.0795	.0859	.0885	.0840	.0836	.0883	.0946	.0976	.136	.161	.193	.0968
600	.0733	.0792	.0814	.0769	.0762	.0788	.0816	.0835	.108	.125	.146	.0896
800	.0641	.0692	.0712	.0669	.0660	.0661	.0669	.0676	.0799	.0885	.0997	.0786
MeV												
1.0	.0576	.0621	.0639	.0599	.0589	.0583	.0578	.0581	.0654	.0708	.0776	.0707
1.5	.0470	.0506	.0520	.0488	.0480	.0470	.0463	.0464	.0497	.0517	.0548	.0575
2.0	.0407	.0439	.0453	.0425	.0420	.0415	.0410	.0411	.0437	.0455	.0475	.0494
3.0	.0338	.0366	.0378	.0362	.0360	.0366	.0367	.0370	.0402	.0418	.0438	.0397
4	.0302	.0328	.0340	.0331	.0332	.0349	.0355	.0359	.0400	.0416	.0435	.0340
5	.0280	.0306	.0317	.0314	.0318	.0344	.0354	.0359	.0407	.0424	.0445	.0303
6	.0267	.0291	.0303	.0305	.0310	.0343	.0357	.0364	.0416	.0435	.0455	.0277
8	.0251	.0276	.0289	.0298	.0306	.0350	.0369	.0378	.0439	.0459	.0480	.0243
10	.0244	.0270	.0283	.0298	.0308	.0362	.0385	.0395	.0464	.0484	.0506	.0222
15	.0244	.0268	.0283	.0307	.0323	.0393	.0425	.0438	.0524	.0548	.0573	.0194
20	.0244	.0273	.0289	.0321	.0339	.0470	.0461	.0476	.0577	.0606	.0636	.0181
30	.0255	.0286	.0305	.0345	.0368	.0470	.0517	.0536	.0659	.0696	.0733	.0171
40	.0266	.0299	.0319	.0365	.0391	.0505	.0557	.0578	.0716	.0757	.0799	.0167
50	.0275	.0310	.0331	.0382	.0410	.0532	.0588	.0611	.0760	.0804	.0850	.0167
60	.0284	.0319	.0342	.0395	.0425	.0553	.0613	.0637	.0794	.0841	.0889	.0167
80	.0296	.0334	.0358	.0416	.0448	.0586	.0651	.0676	.0845	.0896	.0948	.0170
100	.0306	.0345	.0370	.0432	.0465	.0609	.0677	.0704	.0881	.0934	.0984	.0172
150	.0325	.0368	.0394	.0458	.0494	.0648	.0721	.0750	.0939	.0996	.106	.0178
200	.0334	.0377	.0405	.0475	.0511	.0672	.0748	.0778	.0976	.103	.110	.0182
300	.0348	.0393	.0422	.0494	.0532	.0700	.0780	.0811	.102	.108	.115	.0188
400	.0356	.0402	.0432	.0506	.0544	.0716	.0798	.0830	.104	.111	.117	.0192
500	.0361	.0408	.0438	.0514	.0552	.0727	.0810	.0842	.106	.112	.119	.0195
600	.0365	.0412	.0443	.0519	.0558	.0735	.0819	.0851	.107	.113	.121	.0197
800	.0371	.0419	.0450	.0527	.0566	.0745	.0831	.0864	.108	.115	.122	.0200
GeV												
1	.0375	.0423	.0455	.0532	.0572	.0753	.0838	.0871	.109	.116	.123	.0202
1.5	.0380	.0429	.0461	.0539	.0579	.0762	.0849	.0884	.111	.118	.125	.0205
2	.0382	.0432	.0464	.0543	.0583	.0767	.0856	.0890	.111	.118	.126	.0206
3	.0386	.0436	.0468	.0548	.0588	.0773	.0862	.0896	.112	.119	.127	.0208
4	.0387	.0438	.0470	.0550	.0590	.0777	.0865	.0900	.113	.120	.127	.0210
5	.0389	.0439	.0472	.0551	.0591	.0779	.0867	.0902	.113	.120	.128	.021
6	.0389	.0440	.0473	.0552	.0593	.0780	.0868	.0904	.113	.120	.128	.0211
8	.0391	.0441	.0474	.0554	.0594	.0781	.0870	.0905	.113	.120	.128	.0211
10	.0391	.0442	.0475	.0555	.0595	.0783	.0871	.0906	.114	.121	.128	.0212
15	.0392	.0443	.0476	.0556	.0596	.0785	.0873	.0908	.114	.121	.129	.0213
20	.0393	.0443	.0477	.0556	.0596	.0785	.0874	.0910	.114	.121	.129	.0213
30	.0393	.0444	.0477	.0557	.0598	.0786	.0875	.0911	.114	.121	.129	.0213
40	.0393	.0445	.0477	.0557	.0598	.0786	.0876	.0911	.114	.121	.129	.0213
50	.0393	.0445	.0478	.0558	.0598	.0786	.0877	.0911	.114	.121	.129	.0213
60	.0394	.0445	.0478	.0558	.0598	.0787	.0877	.0912	.114	.121	.129	.0214
80	.0394	.0445	.0478	.0558	.0598	.0788	.0877	.0912	.114	.121	.129	.0214
100	.0394	.0445	.0478	.0555	.0598	.0788	.0877	.0912	.114	.121	.129	.0214

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* K edge, + L edge-- Mo 20keV 12.6, 81.7; Sn 29.2keV 7.54, 44.3; I 33.2keV 6.62, 36.4; W 10.2keV 90.7, 235.; 11.5keV 170., 235.; 12.1keV 206., 248.; 69.5keV 2.49, 11.3; Pb 13.0keV 67.8, 166.; 15.2keV 112., 146.; 15.9keV 130., 157.; 88.0keV 1.83, 7.45; U 17.2keV 45.8, 106.; 20.9keV 62.7, 88.0; 21.8keV 79.8, 91.8; 116keV 1.34, 4.86.

MASS ATTENUATION COEFFICIENTS--Continued

Photon Energy	SiO_2	NaI	Air	Concrete	0.8N H_2SO_4	Bone	Muscle	Polystyrene	Lucite	Polyethylene	Bakelite	Pyrex Glass
keV												
10	19.0	139.	4.99	26.9	5.76	20.3	5.27	2.13	3.25	2.01	2.76	17.1
15	5.73	47.4	1.55	8.24	1.76	6.32	1.63	0.755	1.06	0.728	0.923	5.14
20	2.49	22.3	0.752	3.59	0.849	2.79	0.793	.424	0.551	.420	.492	2.25
30	0.859	7.45*	.349	1.19	.391	0.962	.373	.259	.298	.266	.277	0.786
40	.463	19.3	.248	0.605	.276	.512	.268	.217	.234	.226	.223	.431
50	.318	10.7	.208	.392	.231	.349	.227	.199	.208	.209	.200	.302
60	.252	6.62	.188	.295	.208	.274	.205	.188	.193	.198	.187	.242
80	.194	3.12	.167	.213	.185	.209	.183	.173	.176	.183	.171	.190
100	.169	1.72	.154	.179	.171	.180	.170	.163	.164	.172	.161	.166
150	.140	0.625	.136	.144	.150	.149	.149	.145	.146	.154	.143	.139
200	.126	.334	.123	.127	.137	.133	.136	.132	.133	.140	.130	.125
300	.108	.167	.107	.108	.118	.114	.118	.115	.115	.122	.113	.107
400	.0959	.117	.0954	.0963	.106	.102	.105	.103	.103	.109	.101	.0954
500	.0874	.0955	.0870	.0877	.0965	.0927	.0960	.0938	.0941	.0995	.0921	.0870
600	.0808	.0826	.0805	.0810	.0893	.0857	.0888	.0868	.0871	.0921	.0852	.0804
800	.0707	.0676	.0707	.0709	.0783	.0752	.0779	.0763	.0765	.0809	.0749	.0704
MeV												
1.0	.0636	.0586	.0636	.0637	.0704	.0676	.0700	.0685	.0687	.0727	.0673	.0633
1.5	.0518	.0469	.0518	.0519	.0573	.0550	.0570	.0558	.0559	.0592	.0548	.0516
2.0	.0447	.0413	.0445	.0448	.0492	.0473	.0489	.0478	.0480	.0507	.0470	.0444
3.0	.0363	.0366	.0358	.0365	.0396	.0383	.0393	.0383	.0385	.0405	.0377	.0361
4	.0317	.0351	.0308	.0319	.0340	.0331	.0337	.0327	.0329	.0345	.0322	.0314
5	.0287	.0346	.0275	.0290	.0303	.0297	.0300	.0290	.0292	.0305	.0286	.0282
6	.0266	.0347	.0252	.0270	.0277	.0274	.0274	.0263	.0266	.0277	.0260	.0263
8	.0241	.0355	.0223	.0245	.0243	.0244	.0240	.0228	.0232	.0239	.0227	.0237
10	.0226	.0368	.0204	.0231	.0222	.0226	.0219	.0206	.0211	.0215	.0206	.0222
15	.0209	.0402	.0181	.0215	.0194	.0204	.0192	.0176	.0182	.0182	.0178	.0204
20	.0203	.0433	.0170	.0210	.0182	.0194	.0179	.0162	.0168	.0166	.0164	.0198
30	.0202	.0484	.0162	.0210	.0172	.0189	.0168	.0149	.0157	.0151	.0153	.0195
40	.0204	.0520	.0161	.0213	.0169	.0189	.0165	.0144	.0153	.0145	.0148	.0198
50	.0208	.0548	.0161	.0218	.0168	.0190	.0164	.0142	.0151	.0142	.0147	.0201
60	.0212	.0571	.0162	.0222	.0169	.0193	.0165	.0142	.0151	.0141	.0147	.0204
80	.0218	.0605	.0165	.0229	.0171	.0197	.0167	.0142	.0152	.0141	.0148	.0210
100	.0224	.0629	.0168	.0235	.0174	.0201	.0170	.0144	.0154	.0142	.0150	.0215
150	.0234	.0670	.0174	.0247	.0180	.0210	.0175	.0147	.0159	.0145	.0154	.0225
200	.0241	.0695	.0179	.0254	.0184	.0215	.0179	.0150	.0162	.0147	.0157	.0232
300	.0250	.0724	.0185	.0264	.0190	.0223	.0185	.0155	.0167	.0152	.0162	.0240
400	.0256	.0741	.0189	.0269	.0194	.0228	.0189	.0158	.0171	.0155	.0166	.0245
500	.0260	.0752	.0192	.0273	.0197	.0231	.0192	.0160	.0173	.0157	.0168	.0249
600	.0262	.0760	.0194	.0276	.0199	.0233	.0194	.0162	.0175	.0159	.0170	.0252
800	.0266	.0771	.0197	.0281	.0202	.0237	.0197	.0165	.0178	.0161	.0173	.0256
GeV												
1	.0269	.0778	.0199	.0283	.0204	.0239	.0199	.0166	.0180	.0163	.0174	.0258
1.5	.0273	.0789	.0202	.0287	.0207	.0243	.0202	.0169	.0182	.0165	.0177	.0262
2	.0275	.0794	.0204	.0290	.0209	.0245	.0203	.0171	.0184	.0167	.0179	.0264
3	.0278	.0800	.0206	.0292	.0211	.0247	.0205	.0173	.0186	.0169	.0181	.0267
4	.0279	.0803	.0207	.0294	.0212	.0249	.0206	.0174	.0187	.0170	.0182	.0268
5	.0280	.0805	.0208	.0295	.0213	.0249	.0207	.0174	.0188	.0170	.0183	.0269
6	.0281	.0807	.0208	.0295	.0213	.0250	.0208	.0175	.0188	.0171	.0183	.0269
8	.0281	.0808	.0209	.0296	.0214	.0251	.0208	.0175	.0189	.0172	.0184	.0270
10	.0282	.0809	.0209	.0297	.0214	.0251	.0209	.0176	.0189	.0172	.0184	.0271
15	.0283	.0811	.0210	.0298	.0215	.0252	.0209	.0176	.0190	.0173	.0185	.0271
20	.0283	.0812	.0210	.0298	.0215	.0252	.0210	.0177	.0190	.0173	.0185	.0272
30	.0283	.0813	.0211	.0298	.0216	.0253	.0210	.0177	.0191	.0173	.0185	.0272
40	.0284	.0813	.0211	.0299	.0216	.0253	.0210	.0177	.0191	.0173	.0186	.0272
50	.0284	.0814	.0211	.0299	.0216	.0253	.0210	.0177	.0191	.0173	.0186	.0272
60	.0284	.0814	.0211	.0299	.0216	.0253	.0210	.0177	.0191	.0174	.0186	.0273
80	.0284	.0815	.0211	.0299	.0216	.0253	.0210	.0178	.0191	.0174	.0186	.0273
100	.0284	.0815	.0211	.0299	.0216	.0253	.0211	.0178	.0191	.0174	.0186	.0273

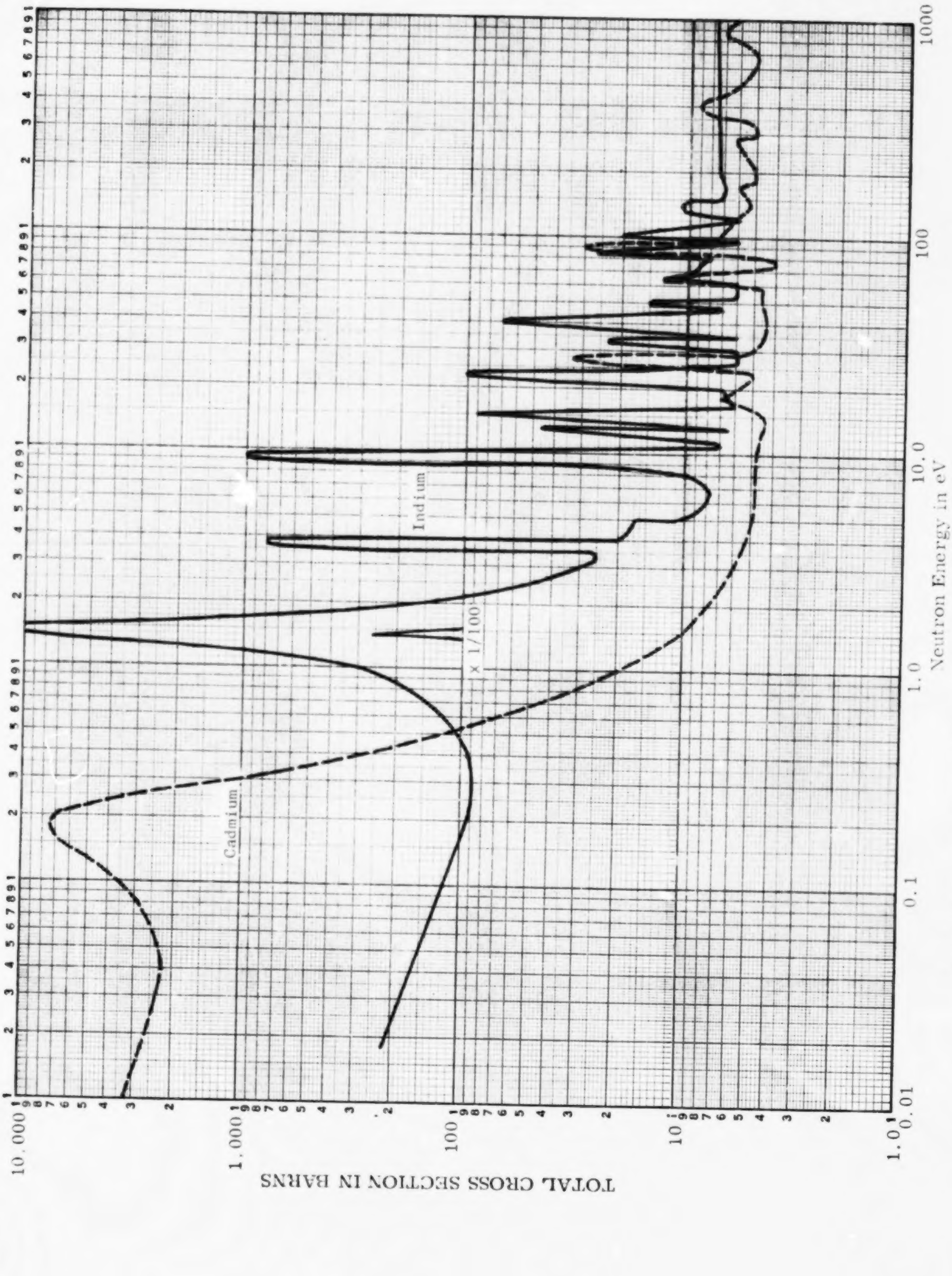
* K edge of Iodine--33.2keV 5.69, 30.9.

VALUES OF THE MASS ENERGY-ABSORPTION COEFFICIENTS

Photon Energy (MeV)	Mass Energy-Absorption Coefficient, (μ_{en}/ρ), cm^2/g			
	Water	Air	Compact Bone	Muscle
0.010	4.89	4.66	19.0	4.96
.015	1.32	1.29	5.89	1.36
.020	0.523	0.516	2.51	0.544
.030	.147	.147	0.743	.154
.040	.0647	.0640	.305	.0677
.050	.0394	.0384	.158	.0409
.060	.0304	.0292	.0979	.0312
.080	.0253	.0236	.0520	.0255
.10	.0252	.0231	.0386	.0252
.15	.0278	.0251	.0304	.0276
.20	.0300	.0268	.0302	.0297
.30	.0320	.0288	.0311	.0317
.40	.0329	.0296	.0316	.0325
.50	.0330	.0297	.0316	.0327
.60	.0329	.0296	.0315	.0326
.80	.0321	.0289	.0306	.0318
1.0	.0311	.0280	.0297	.0308
1.5	.0283	.0255	.0270	.0281
2.0	.0260	.0234	.0248	.0257
3.0	.0227	.0205	.0219	.0225
4.0	.0205	.0186	.0199	.0203
5.0	.0190	.0173	.0186	.0188
6.0	.0180	.0163	.0178	.0178
8.0	.0165	.0150	.0165	.0163
10.0	.0155	.0144	.0159	.0154

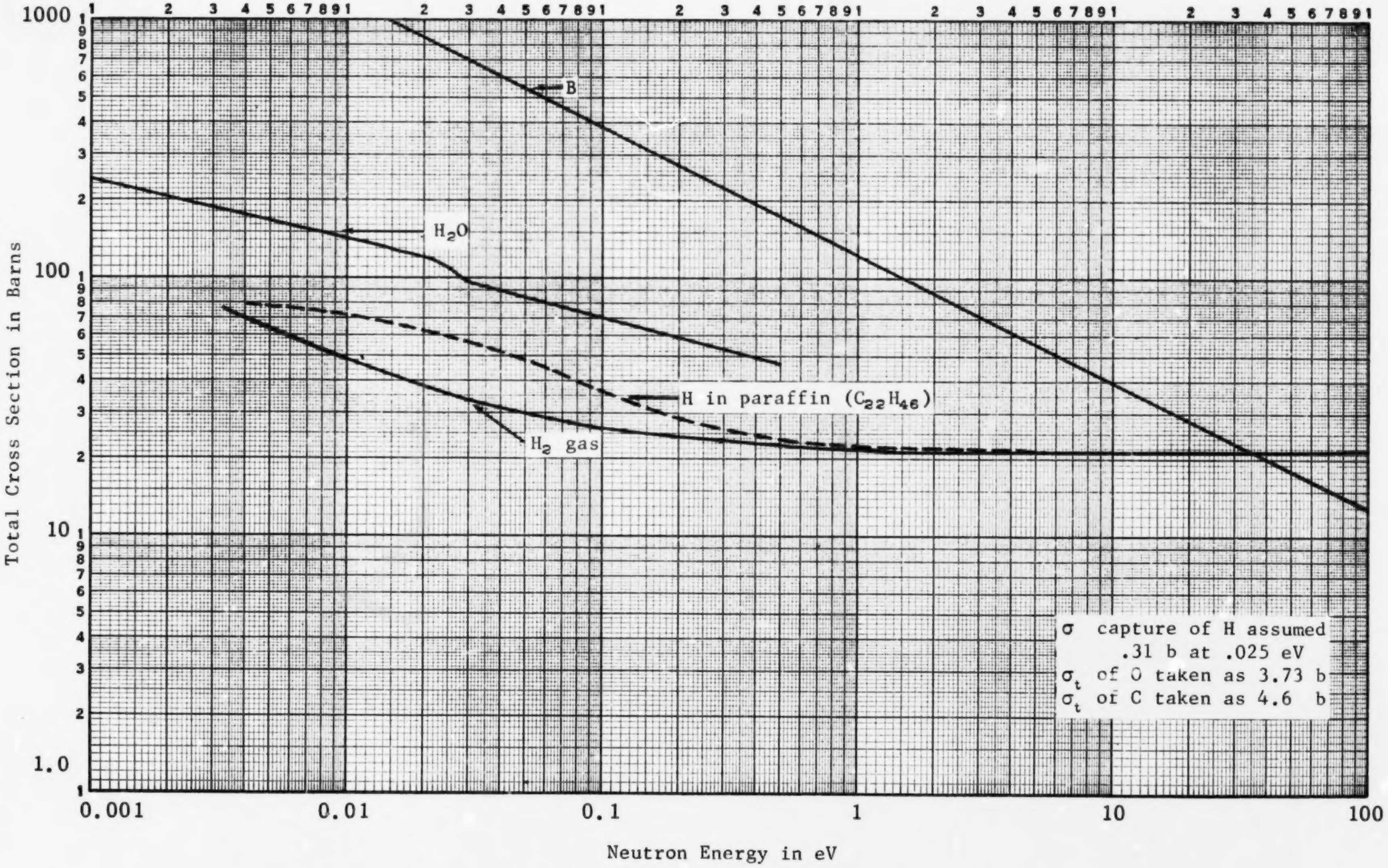
Source: Physical Aspects of Irradiation (NBS Handbook No. 85 [Washington, D.C.: Supt. of Docs., U.S. Government Printing Office, Mar. 1964]), p. 3.

TOTAL NEUTRON CROSS SECTIONS FOR INDIUM AND CADMIUM



Data taken from BNL-325

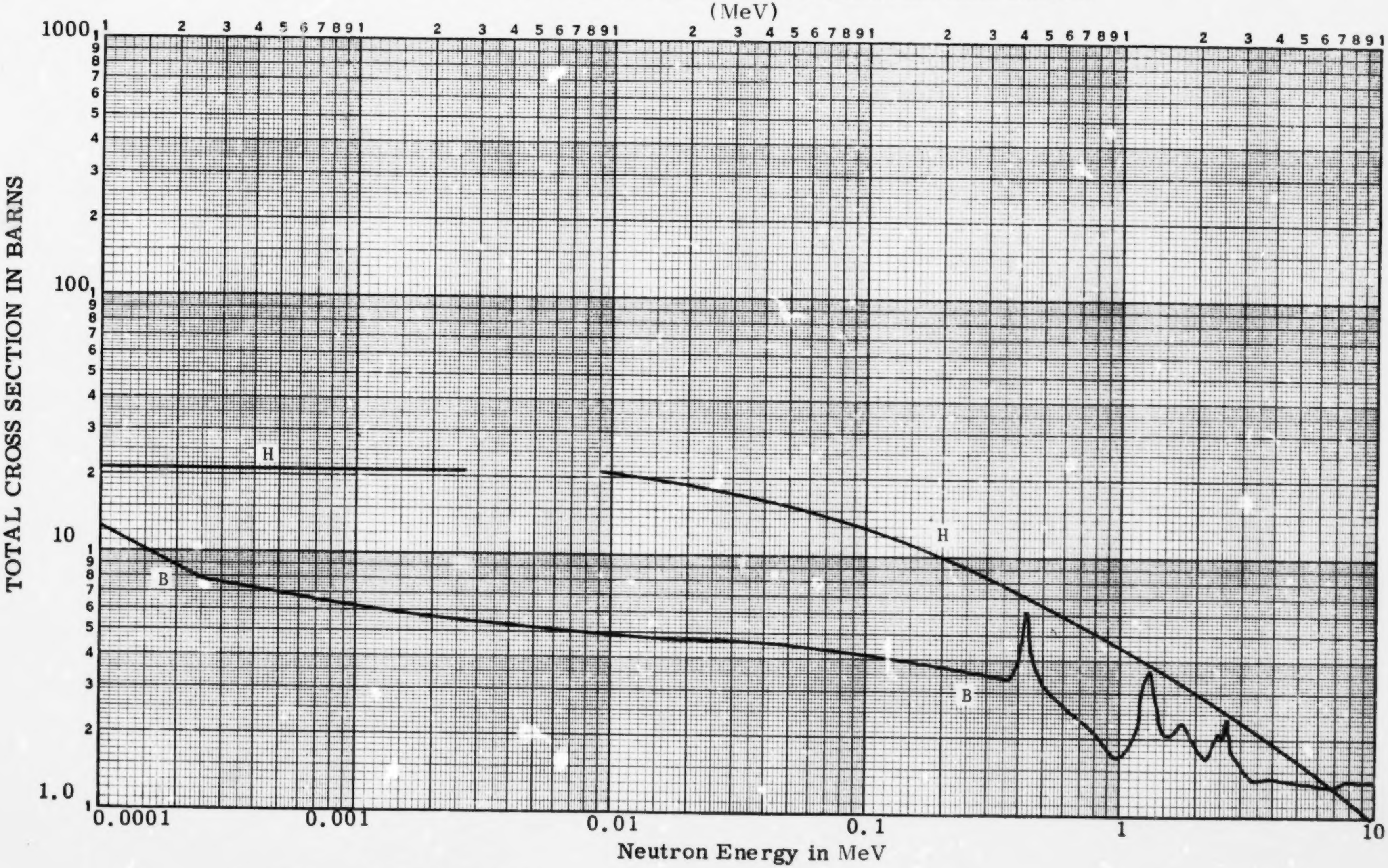
NEUTRON CROSS SECTIONS FOR HYDROGEN AND BORON
(eV)



σ capture of H assumed .31 b at .025 eV
σ_t of O taken as 3.73 b
σ_t of C taken as 4.6 b

Cross sections for boron, H_2, and H_2O taken from BNL-325; for H in paraffin from Havens and Rainwater, Phys. Rev., 73, 7, 733-741 (1948).

NEUTRON CROSS SECTIONS FOR HYDROGEN AND BORON



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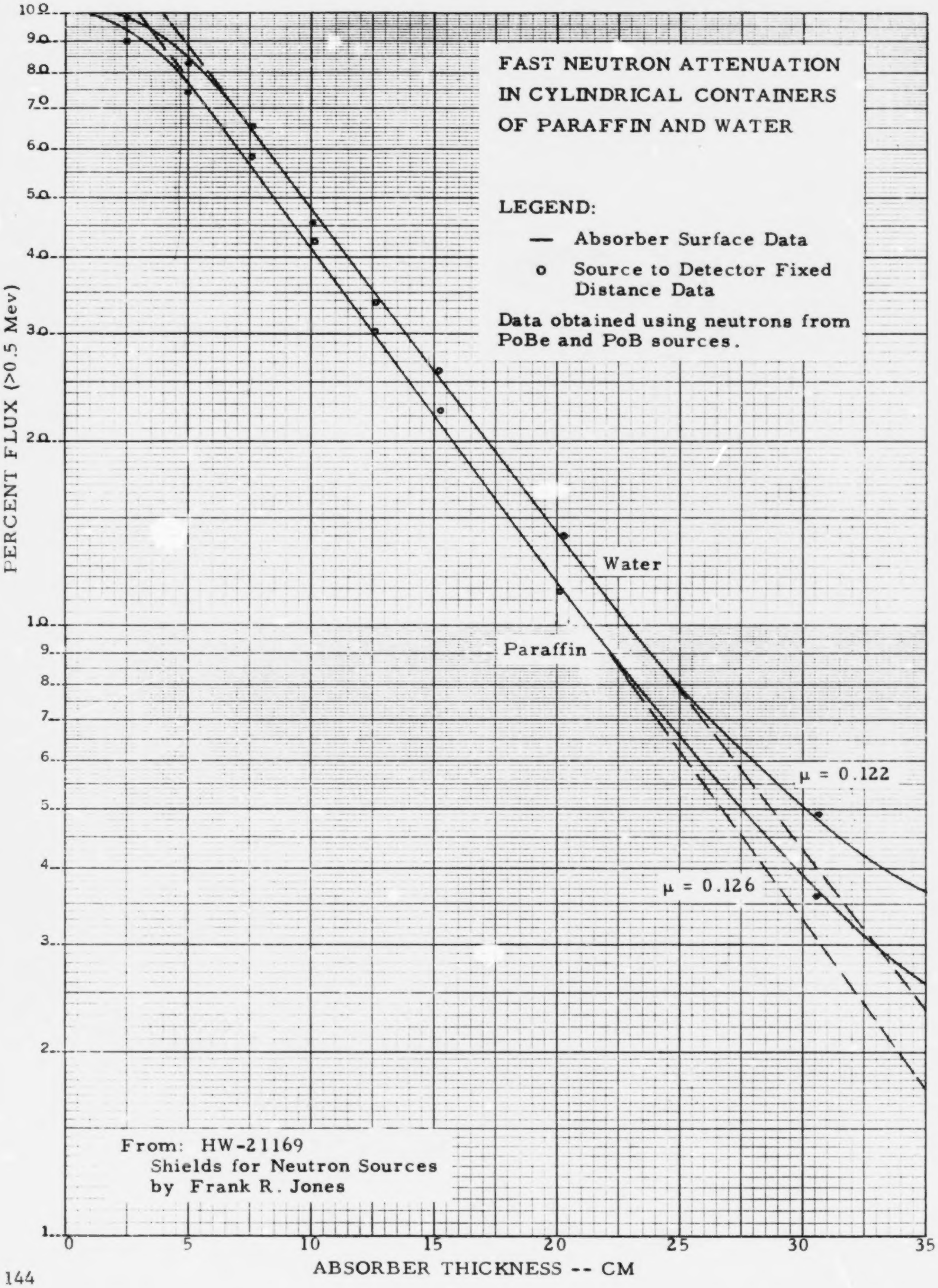


FAST NEUTRON ATTENUATION IN CYLINDRICAL CONTAINERS OF PARAFFIN AND WATER

From: HW-21169
Shields for Neutron Sources
by Frank R. Jones

DOSE BUILDUP FACTORS

$$\dot{X} = B\dot{X}_0 e^{-\mu x}$$

where $\dot{X}$ = exposure rate, shielding present

B = buildup factor

$\dot{X}_0$ = exposure rate, same location as $\dot{X}$, no shielding

μ = linear ~~absorption~~ attenuation coefficient

x = shield thickness

Dose Buildup Factor (B) for a Point Isotropic Source

Material	MeV	μx*						
		1	2	4	7	10	15	20
Water	0.255	3.09	7.14	23.0	72.9	166	456	982
	0.5	2.52	5.14	14.3	38.8	77.6	178	334
	1.0	2.13	3.71	7.68	16.2	27.1	50.4	82.2
	2.0	1.83	2.77	4.88	8.46	12.4	19.5	27.7
	3.0	1.69	2.42	3.91	6.23	8.63	12.8	17.0
	4.0	1.58	2.17	3.34	5.13	6.94	9.97	12.9
	6.0	1.46	1.91	2.76	3.99	5.18	7.09	8.85
	8.0	1.38	1.74	2.40	3.34	4.25	5.66	6.95
	10.0	1.33	1.63	2.19	2.97	3.72	4.90	5.98
Aluminum	0.5	2.37	4.24	9.47	21.5	38.9	80.8	141
	1.0	2.02	3.31	6.57	13.1	21.2	37.9	58.5
	2.0	1.75	2.61	4.62	8.05	11.9	18.7	26.3
	3.0	1.64	2.32	3.78	6.14	8.65	13.0	17.7
	4.0	1.53	2.08	3.22	5.01	6.88	10.1	13.4
	6.0	1.42	1.85	2.70	4.06	5.49	7.97	10.4
	8.0	1.34	1.68	2.37	3.45	4.58	6.56	8.52
	10.0	1.28	1.55	2.12	3.01	3.96	5.63	7.32
Iron	0.5	1.98	3.09	5.98	11.7	19.2	35.4	55.6
	1.0	1.87	2.89	5.39	10.2	16.2	28.3	42.7
	2.0	1.76	2.43	4.13	7.25	10.9	17.6	25.1
	3.0	1.55	2.15	3.51	5.85	8.51	13.5	19.1
	4.0	1.45	1.94	3.03	4.91	7.11	11.2	16.0
	6.0	1.34	1.72	2.58	4.14	6.02	9.89	14.7
	8.0	1.27	1.56	2.23	3.49	5.07	8.50	13.0
	10.0	1.20	1.42	1.95	2.99	4.35	7.54	12.4

* μx = mass ~~absorption~~ attenuation coefficient (μ/ρ) × shield thickness (cm) × shield density (g/cm^2).

NOTE: For concrete use an average of aluminum and iron; e.g., B(conc) = [B(iron) + B(Al)] ÷ 2.

DOSE BUILDUP FACTORS--Continued

Point Isotropic Source--Continued

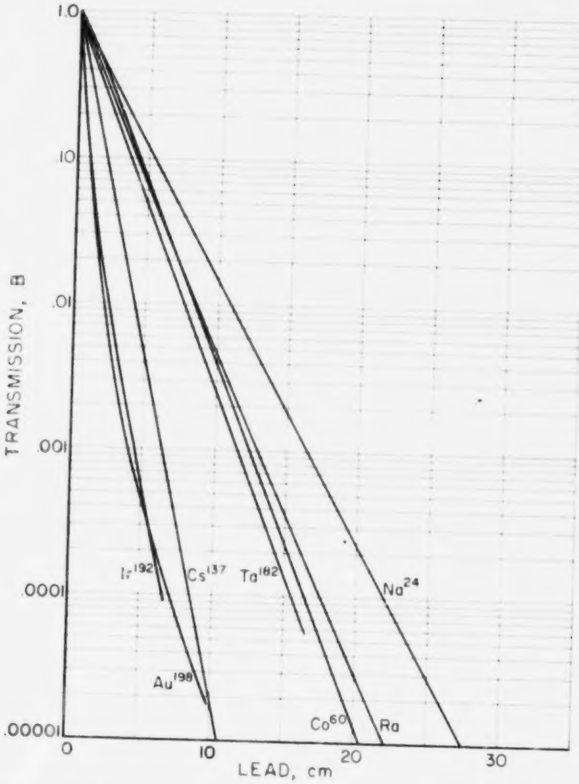
Material	MeV	μx*						
		1	2	4	7	10	15	20
Tin	0.5	1.56	2.08	3.09	4.57	6.04	8.64	--
	1.0	1.64	2.30	3.74	6.17	8.85	13.7	18.8
	2.0	1.57	2.17	3.53	5.87	8.53	13.6	19.3
	3.0	1.46	1.96	3.13	5.28	7.91	13.3	20.1
	4.0	1.38	1.81	2.82	4.82	7.41	13.2	21.2
	6.0	1.26	1.57	2.37	4.17	6.94	14.8	29.1
	8.0	1.19	1.42	2.05	3.57	6.19	15.1	34.0
	10.0	1.14	1.31	1.79	2.99	5.21	12.5	33.4
Tungsten	0.5	1.28	1.50	1.84	2.24	2.61	3.12	--
	1.0	1.44	1.83	2.57	3.62	4.64	6.25	(7.35)
	2.0	1.42	1.85	2.72	4.09	5.27	8.07	(10.6)
	3.0	1.36	1.74	2.59	4.00	5.92	9.66	14.1
	4.0	1.29	1.62	2.41	4.03	6.27	12.0	20.9
	6.0	1.20	1.43	2.07	3.60	6.29	15.7	36.3
	8.0	1.14	1.32	1.81	3.05	5.40	15.2	41.9
	10.0	1.11	1.25	1.64	2.62	4.65	14.0	39.3
Lead	0.5	1.24	1.42	1.69	2.00	2.27	2.65	(2.73)
	1.0	1.37	1.69	2.26	3.02	3.74	4.81	5.86
	2.0	1.39	1.76	2.51	3.66	4.84	6.87	9.00
	3.0	1.34	1.68	2.43	2.75	5.30	8.44	12.3
	4.0	1.27	1.56	2.25	3.61	5.44	9.80	16.3
	5.1097	1.21	1.46	2.08	3.44	5.55	11.7	23.6
	6.0	1.18	1.40	1.97	3.34	5.69	13.8	32.7
	8.0	1.14	1.30	1.74	2.89	5.07	14.1	44.6
	10.0	1.11	1.23	1.58	2.52	4.34	12.5	39.2
Uranium	0.5	1.17	1.30	1.48	1.67	1.85	2.08	--
	1.0	1.31	1.56	1.98	2.50	2.97	3.67	--
	2.0	1.33	1.64	2.23	3.09	3.95	5.36	(6.48)
	3.0	1.29	1.58	2.21	3.27	4.51	6.97	9.88
	4.0	1.24	1.50	2.09	3.21	4.66	8.01	12.7
	6.0	1.16	1.36	1.85	2.96	4.80	10.8	23.0
	8.0	1.12	1.27	1.66	2.61	4.36	11.2	28.0
	10.0	1.09	1.20	1.51	2.26	3.78	10.5	28.5

* μx = mass ~~absorption~~ attenuation coefficient (μ/ρ) X shield thickness (cm) X shield density (g/cm^2).

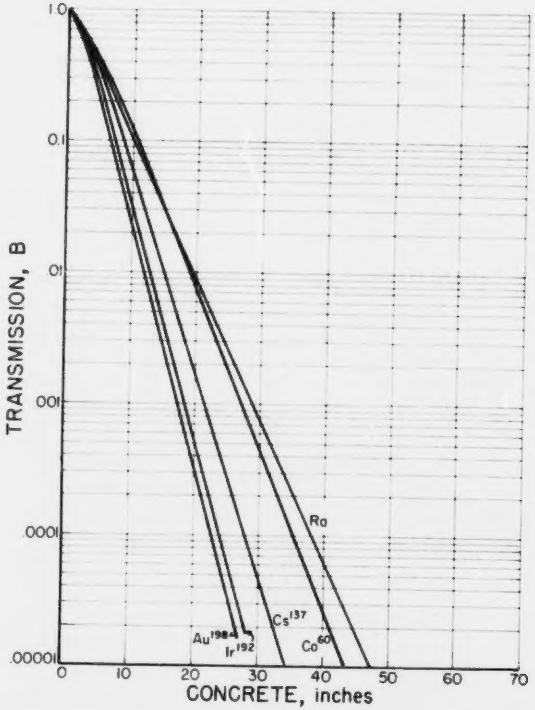
Dose Buildup Factor (B) for a Plane Monodirectional Source

Material	MeV	μx*					
		1	2	4	7	10	15
Water	0.5	2.63	4.29	9.05	20.0	35.9	74.9
	1.0	2.26	3.39	6.27	11.5	18.0	30.8
	2.0	1.84	2.63	4.28	6.96	9.87	14.4
	3.0	1.69	2.31	3.57	5.51	7.48	10.8
	4.0	1.58	2.10	3.12	4.63	6.19	8.54
	6.0	1.45	1.86	2.63	3.76	4.86	6.78
	8.0	1.36	1.69	2.30	3.16	4.00	5.47
Iron	0.5	2.07	2.94	4.87	8.31	12.4	20.6
	1.0	1.92	2.74	4.57	7.81	11.6	18.9
	2.0	1.69	2.35	3.76	6.11	8.78	13.7
	3.0	1.58	2.13	3.32	5.26	7.41	11.4
	4.0	1.48	1.90	2.95	4.61	6.46	9.92
	6.0	1.35	1.71	2.48	3.81	5.35	8.39
	8.0	1.27	1.55	2.17	3.27	4.58	7.33
	10.0	1.22	1.44	1.95	2.89	4.07	6.70
Tin	1.0	1.65	2.24	3.40	5.18	7.19	10.5
	2.0	1.58	2.13	3.27	5.12	7.13	11.0
	4.0	1.39	1.80	2.69	4.31	6.30	---
	6.0	1.27	1.57	2.27	3.72	5.77	11.0
	10.0	1.16	1.33	1.77	2.81	4.53	9.68
Lead	0.5	1.24	1.39	1.63	1.87	2.08	---
	1.0	1.38	1.68	2.18	2.80	3.40	4.20
	2.0	1.40	1.76	2.41	3.36	4.35	5.94
	3.0	1.36	1.71	2.42	3.55	4.82	7.18
	4.0	1.28	1.56	2.18	3.29	4.69	7.70
	6.0	1.19	1.40	1.87	2.97	4.69	9.53
	8.0	1.14	1.30	1.69	2.61	4.18	9.08
	10.0	1.11	1.24	1.54	2.27	3.54	7.70
Uranium	0.5	1.17	1.28	1.45	1.60	1.73	---
	1.0	1.30	1.53	1.90	2.32	2.70	3.60
	2.0	1.33	1.62	2.15	2.87	3.56	4.89
	3.0	1.29	1.57	2.13	3.02	3.99	5.94
	4.0	1.25	1.49	2.02	2.94	4.06	6.47
	6.0	1.18	1.37	1.82	2.74	4.12	7.79
	8.0	1.13	1.27	1.61	2.39	3.65	7.36
	10.0	1.10	1.21	1.48	2.12	3.21	6.58

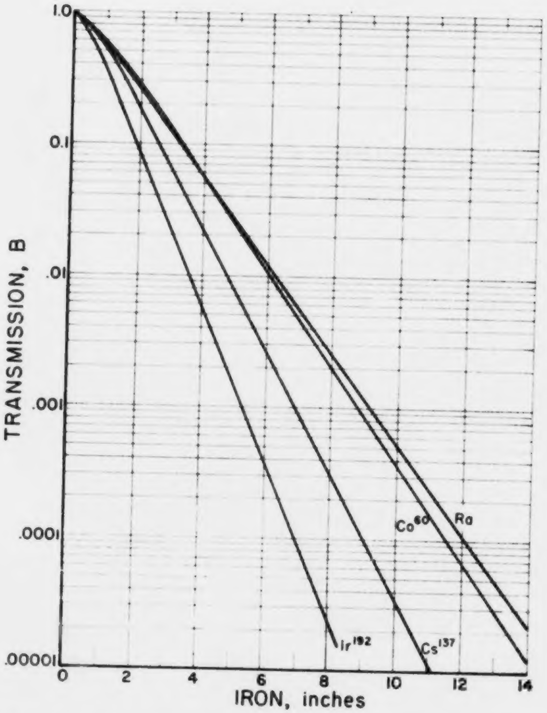
* μx = mass attenuation ~~absorption~~ coefficient (μ/ρ) × shield thickness (cm) × shield density (g/cm^2).



Transmission through lead of gamma rays from radium [14]; cobalt 60, cesium 137, gold 198 [7]; iridium 192 [15]; tantalum 182 and sodium 24 [29].



Transmission through concrete (density 147 lb/ft^3) of gamma rays from radium [14]; cobalt 60, cesium 137, gold 198 [7]; iridium 192 [15].



Transmission through iron of gamma rays from radium [14]; cobalt 60, cesium 137 [7]; iridium 192 [15].

EQUATIONS

Primary Barrier:

$$K = \frac{Pd^2}{WUT}\ , \qquad (1)$$

where

P = maximum permissible dose equivalent
0.1 R/week for controlled areas
0.01 R/week for environs

D = distance in meters (If distance in feet is used, this becomes d/3.28.)

W = workload in ma-min week (This should, insofar as possible, be averaged over a period of at least several months and preferably a year.)

U = use factor

T = occupancy factor.

Secondary Barrier:

Equation (1) may be used for the computation of secondary barriers subject to the following modifications:

(a) For scattered radiation from useful beams generated at 500 kVcp or less,

$$K = \frac{1{,}000 \times P \times d^2}{WT} \quad \text{(Use curve for kV of useful beam.)} \qquad (2)^*$$

(b) For scattered radiation from useful beams generated at 1,000 kVcp,

$$K = \frac{1{,}000 \times P \times d^2}{20\ WT} \quad \text{(Use 500 kVcp curve.)} \qquad (3)^\dagger$$

(c) For scattered radiation from useful beams generated at 2,000 kVcp,

$$K = \frac{1{,}000 \times P \times d^2}{120\ WT} \quad \text{(Use 500 kVcp curve.)} \qquad (4)^\dagger$$

(d) For scattered radiation from useful beams generated at 3,000 kVcp,

$$K = \frac{1{,}000 \times P \times d^2}{300\ WT} \quad \text{(Use 500 kVcp curve.)} \qquad (5)^\dagger$$

---

*If a 50-cm FSD is used divide K by 4.
†If a 70-cm FSD is used divide K by 2.

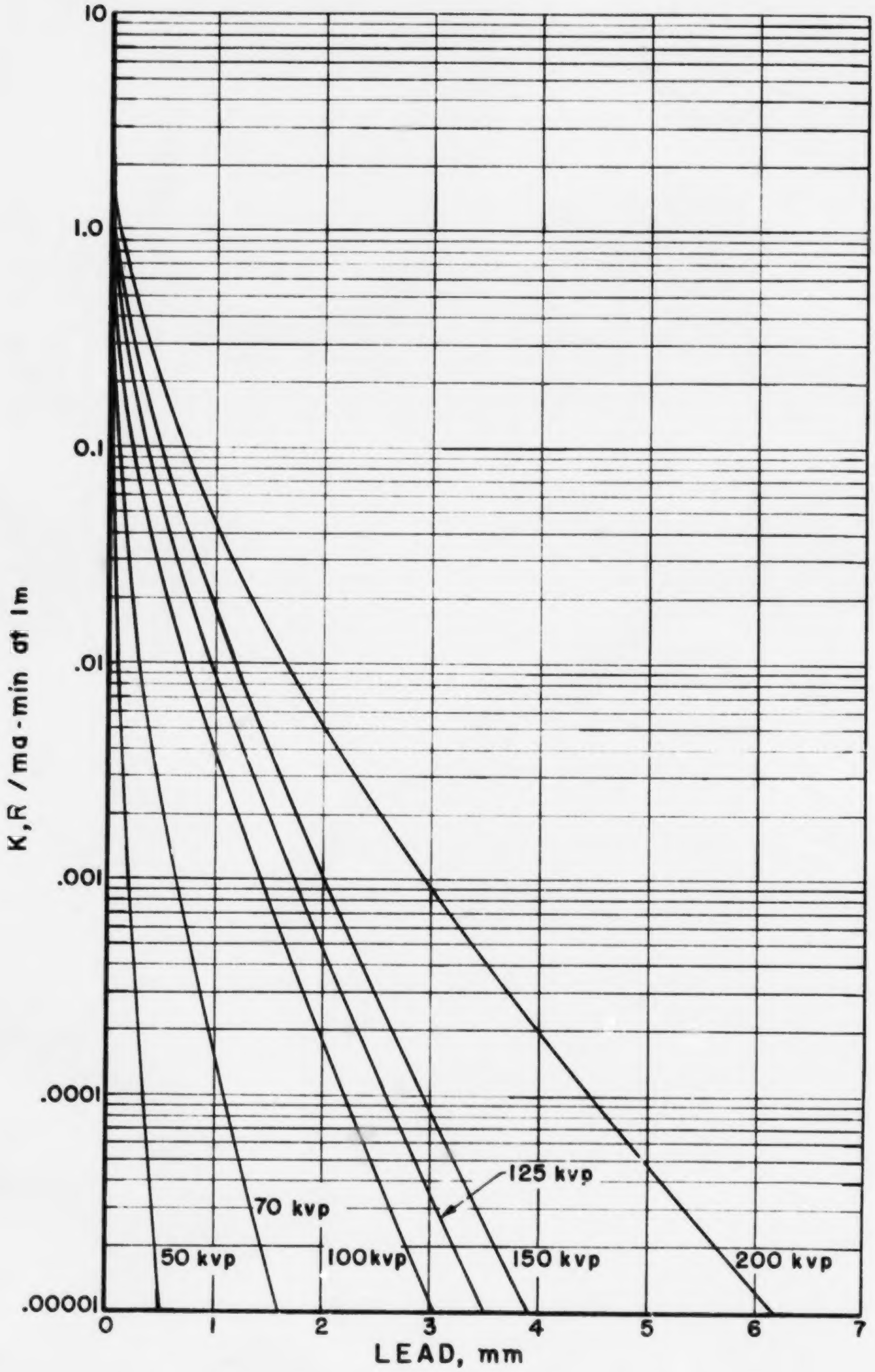


FIGURE 17. *Attenuation in lead of x rays produced by potentials of 50- to 200-kv peak.*

The measurements were made with a 90° angle between the electron beam and the axis o the x-ray beam and with a pulsed waveform. The curves at 50 and 70 kvp were obtained by interpolation and extrapolation of available data (Braestrup, 1944) [2]. The filtrations were 0.5 mm of aluminum for 50, 70, 100, and 125 kvp, and 3 mm of aluminum for 150 and 200 kvp [26].

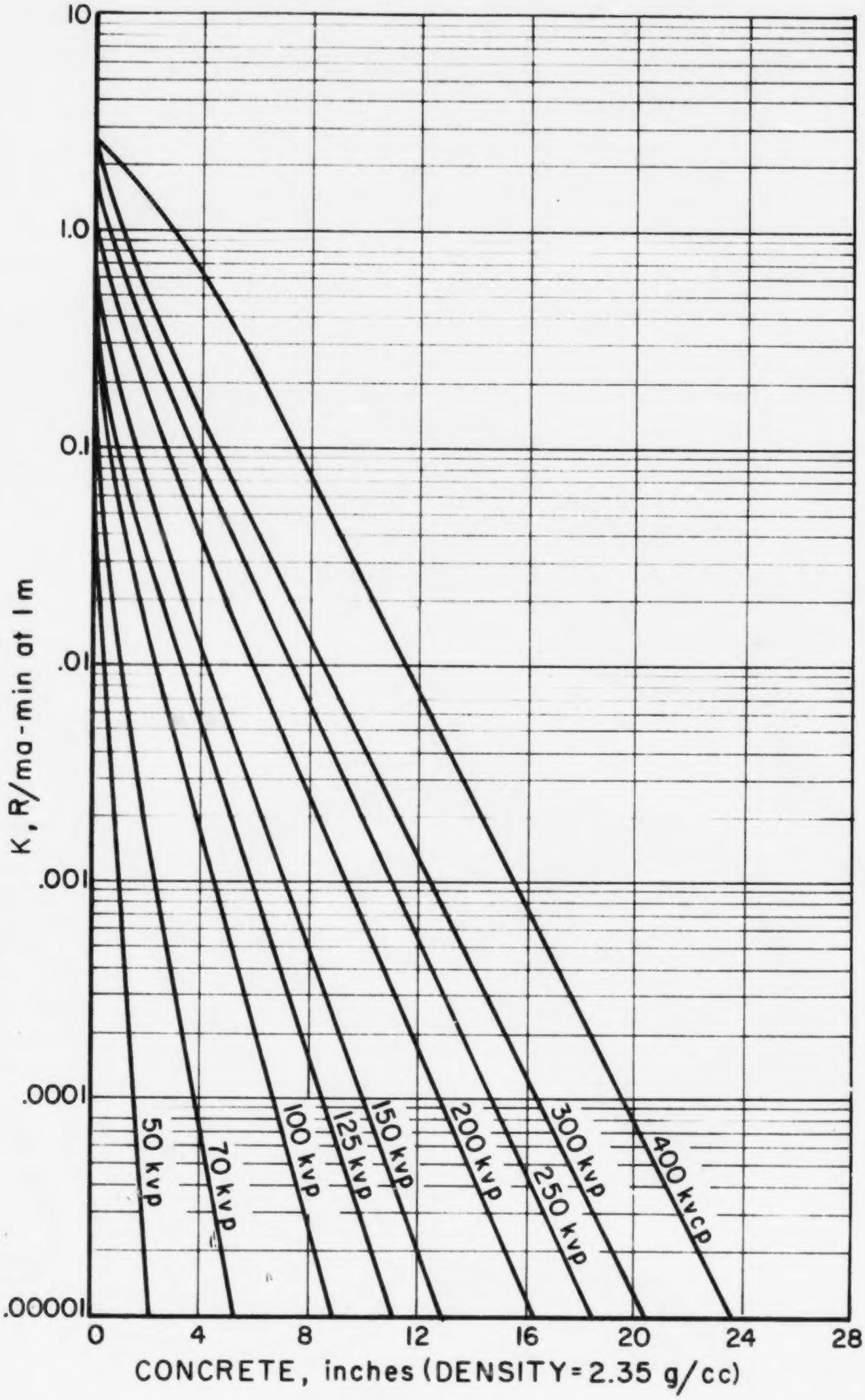


FIGURE 18. *Attenuation in concrete of x rays produced by potentials of 50 to 400 kv.*

The measurements were made with a 90° angle between the electron beam and the axis of the x-ray beam. The curves for 50 to 300 kvp are for a pulsed waveform. The filtrations were 1 mm of aluminum for 70 kvp, 2 mm of aluminum for 100 kvp, and 3 mm of aluminum for 125 to 300 kvp (Trout et al., 1955 and 1959) [11]. The 400-kvcp curve was interpolated from data obtained with a constant potential generator and inherent filtration of approximately 3 mm of copper (Miller and Kennedy, 1955) [8] [26].

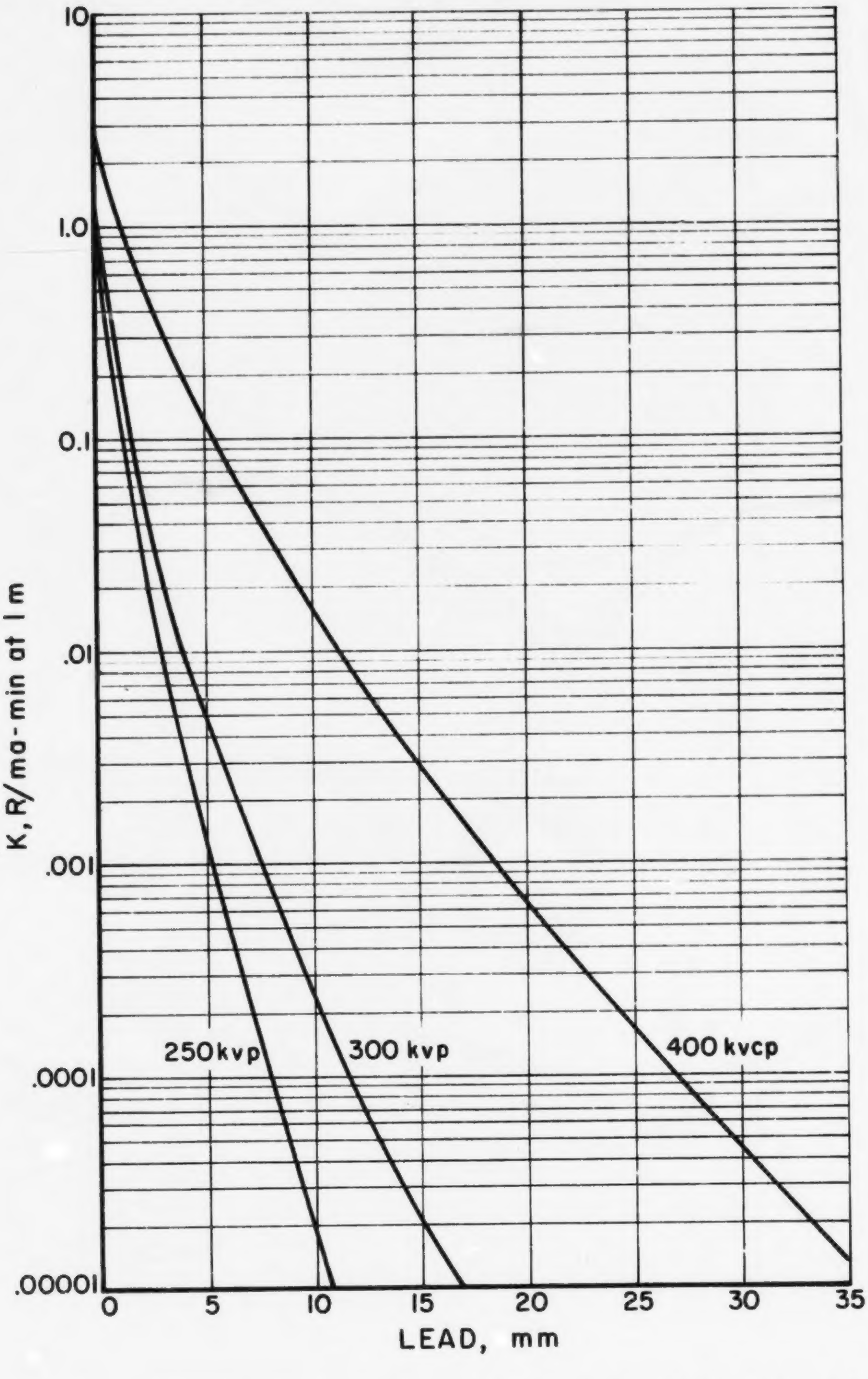


Figure 19. *Attenuation in lead of x rays produced by potentials of 250 to 400 kv.*

The measurements were made with a 90° angle between the electron beam and the axis of the x-ray beam. The 250-kvp curve is for a pulsed waveform and a filtration of 3 mm of aluminum (Braestrup, 1944) [2]. The 400-kvcp curve was obtained with a constant potential generator and inherent filtration of approximately 3 mm of copper (Miller and Kennedy, 1955) [8]. The 300-kvp curve is for pulsed waveform and 3 mm of aluminum (Trout et al., 1959) [11] [26].

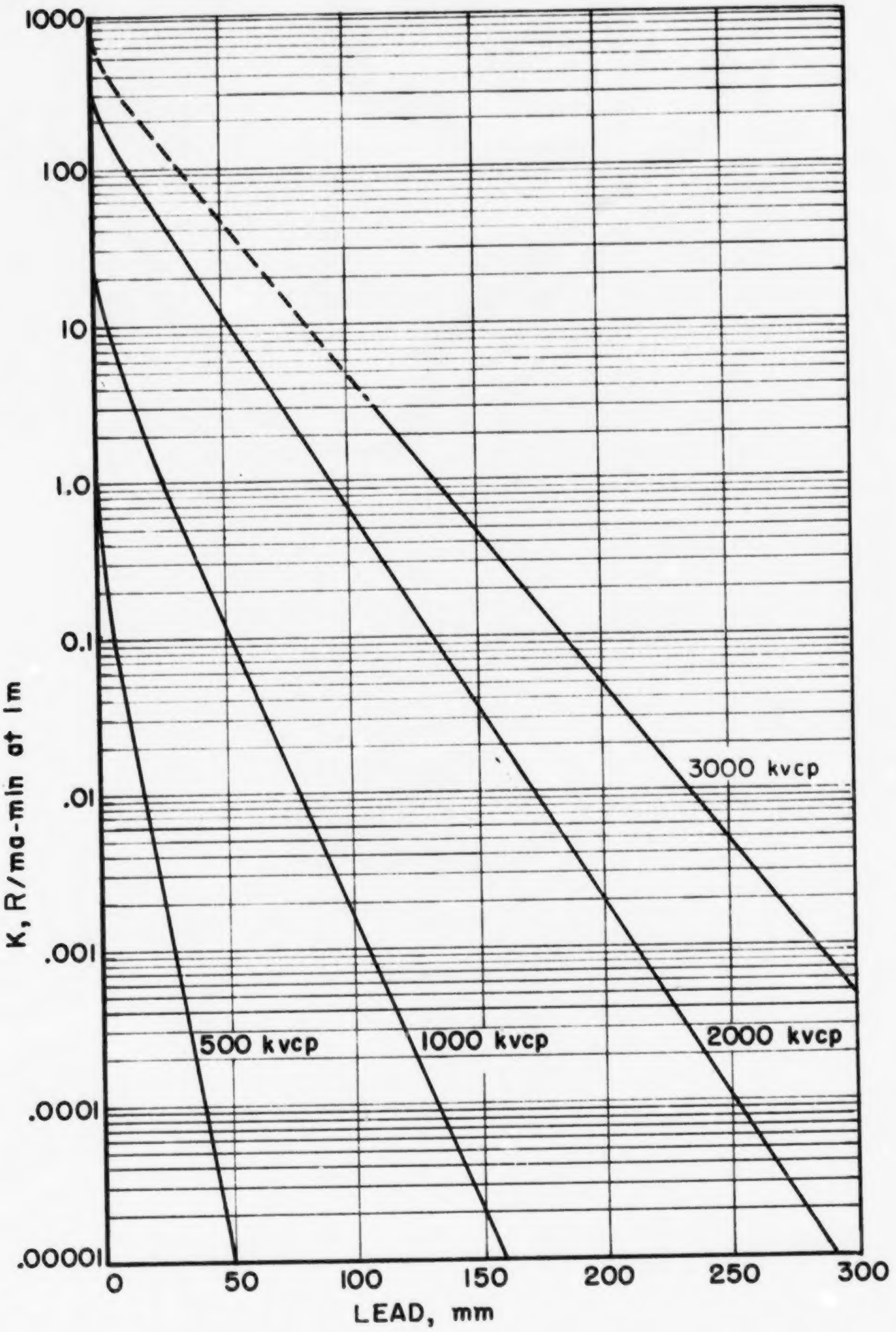


FIGURE 20. *Attenuation in lead of x rays produced by potentials of 500- to 3,000-kv constant potential.*

The measurements were made with a 0° angle between the electron beam and the axis of the x-ray beam and with a constant potential generator. The 500- and 1,000-kvcp curve were obtained with filtration of 2.88 mm of tungsten, 2.8 mm of copper, 2.1 mm of brass, and 18.7 mm of water (Wyckoff et al., 1948) [13]. The 2,000-kvcp curve was obtained by extrapolating to broad-beam conditions (E.E. Smith) the data of Evans et al., 1952 [3]. The inherent filtration was equivalent to 6.8 mm of lead. The 3,000-kvcp curve has been obtained by interpolation of the 2,000-kvcp curve given herein, and the data of Miller and Kennedy, 1956 [9].

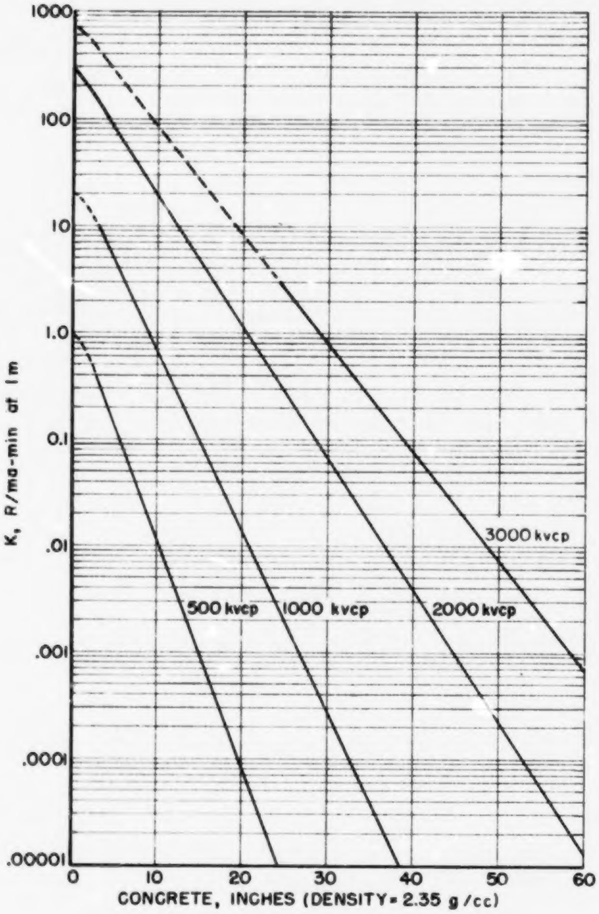


FIGURE 21. *Attenuation in concrete of x rays produced by potentials of 500- to 3,000-kv constant potential.*

The measurements were made with a 0° angle between the electron beam and the axis of the x-ray beam and with a constant potential generator. The 500- and 1,000-kvcp curves were obtained with filtration of 2.8 mm of copper, 2.1 mm of brass, and 18.7 mm of water (Wyckoff et al., 1948) [13]. The 2,000-kvcp curve was obtained by extrapolating to broad-beam conditions (E.E. Smith) the data of Evans et al., 1952 [3]. The inherent filtration was equivalent to 6.8 mm of lead. The 3,000-kvcp curve has been obtained by interpolation of the 2,000-kvcp curve given herein, and the data of Kirn and Kennedy, 1954 [5].

TABLE 12. *Half-value layer*

[Approximate half-value layers *obtained at high filtration* for the indicated tube potentials under broad-beam conditions]

Attenuating material	hvl for various tube potentials												
	50 kvp	70 kvp	100 kvp	125 kvp	150 kvp	200 kvp	250 kvp	300 kvp	400 kvcp	500 kvcp	1,000 kvcp	2,000 kvcp	3,000 kvcp
Lead (mm)	0.05	0.18	0.24	0.27	0.3	0.5	0.8	1.3	2.2	3.6	8.0	12.0	15.0
Concrete (in.)	.2	.5	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.8	2.45	2.95
Concrete (cm)	.51	1.27	1.8	2.0	2.3	2.5	2.8	3.0	3.3	3.6	4.6	6.2	7.5

NOTE.—One tenth-value layer is equivalent to 3.33 half-value layers.

Commercial Lead Sheets

Thickness		Approximate Weight
mm	in.	lb/ft^2
0.79	$\frac{1}{32}$	2
1.00	$\frac{5}{128}$	$2\frac{1}{2}$
1.19	$\frac{3}{64}$	3
1.58	$\frac{1}{16}$	4
1.98	$\frac{5}{64}$	5
2.38	$\frac{3}{32}$	6
3.17	$\frac{1}{8}$	8
4.76	$\frac{3}{16}$	12
6.35	$\frac{1}{4}$	16
8.50	$\frac{1}{3}$	20
10.1	$\frac{2}{5}$	24
12.7	$\frac{1}{2}$	30
16.9	$\frac{2}{3}$	40
25.4	1	60

Source: Medical X-Ray Protection up to Three Million Volts (NBS Handbook No. 76 [Washington, D.C.: Supt. of Docs., U.S. Government Printing Office, Feb. 1961]), p. 30.

Thickness of Lead Required to Reduce Useful Beam to 5 Percent[a]

Beam Quality		Required Lead Thickness (mm)
Potential	Half Value Layer (mm)	
60 kVp	1.2 Al	0.10
100 kVp	1.0 Al	0.16
100 kVp	2.0 Al	0.25
100 kVp	3.0 Al	0.35
140 kVp	0.5 Cu	0.7
200 kVp	1.0 Cu	1.0
250 kVp	3.0 Cu	1.7
400 kVp	4.0 Cu	2.3
1000 kVp	3.2 Pb	20.5
2000 kVp	6.0 Pb	43.0
2000 kVcp	14.5 Pb	63.0
3000 kVcp	16.2 Pb	70.0
6000 kV	17.0 Pb	74.0
8000 kV	15.5 Pb	67.0
Cobalt 60	10.4 Pb	47.0

[a] Approximate values for broad beams. Transmission data for brass, steel and other material for potentials up to 2000 kVp may be found in reference [15]. Measurements on 1000 kVp and 2000 kVp made with resonant-type therapy units. Data for 6000 kV taken from reference [16], for a linear accelerator. Data for 2000 kVcp, 3000 kVcp, and 8000 kV derived by interpolation from graph presented in reference [17]. The third column refers to lead or to the required equivalent lead thickness of lead-containing materials (e.g. lead rubber, lead glass, etc.).

Source: Medical X-Ray and Gamma-Ray Protection for Energies up to 10 MeV (NCRP Report No. 33 [Washington, D.C.: National Council on Radiation Protection and Measurements, Feb. 1968]), p. 45.

CONCRETE* EQUIVALENTS (mm) OF LEAD AT DIFFERENT X-RAY TUBE POTENTIALS

Lead Thickness (mm)	Tube Potential			
	150 kVp	200 kVp	300 kVp	400 kVp
1	80	75	56	47
2	150	140	89	70
3	220	200	117	94
4	280	260	140	112
6	---	---	200	140
8	---	---	240	173
10	---	---	280	210
15	---	---	---	280

*Density 2.35 g/cm^3.

IRON EQUIVALENTS (mm) OF LEAD AT DIFFERENT X-RAY TUBE POTENTIALS

Lead Thickness (mm)	Tube Potential						
	150 kVp	200 kVp	300 kVp	400 kVp	600 kVp	800 kVp	1000 kVp
1	11	12	12	11	10	9	8
2	25	27	20	18	16	14	13
3	37	40	28	23	19	17	16
4	50	55	35	28	23	20	18
6	---	---	48	38	30	26	23
8	---	---	60	45	36	31	28
10	---	---	75	55	42	36	32
15	---	---	---	75	55	48	43
20	---	---	---	---	70	60	55
50	---	---	---	---	---	125	110

Data for tables from NBS Handbook No. 50.

TABLE 1.—*Mean milliroentgens per milliampere-second at 12 inches by kilovolt peak and filtration categories for dental X-ray units*

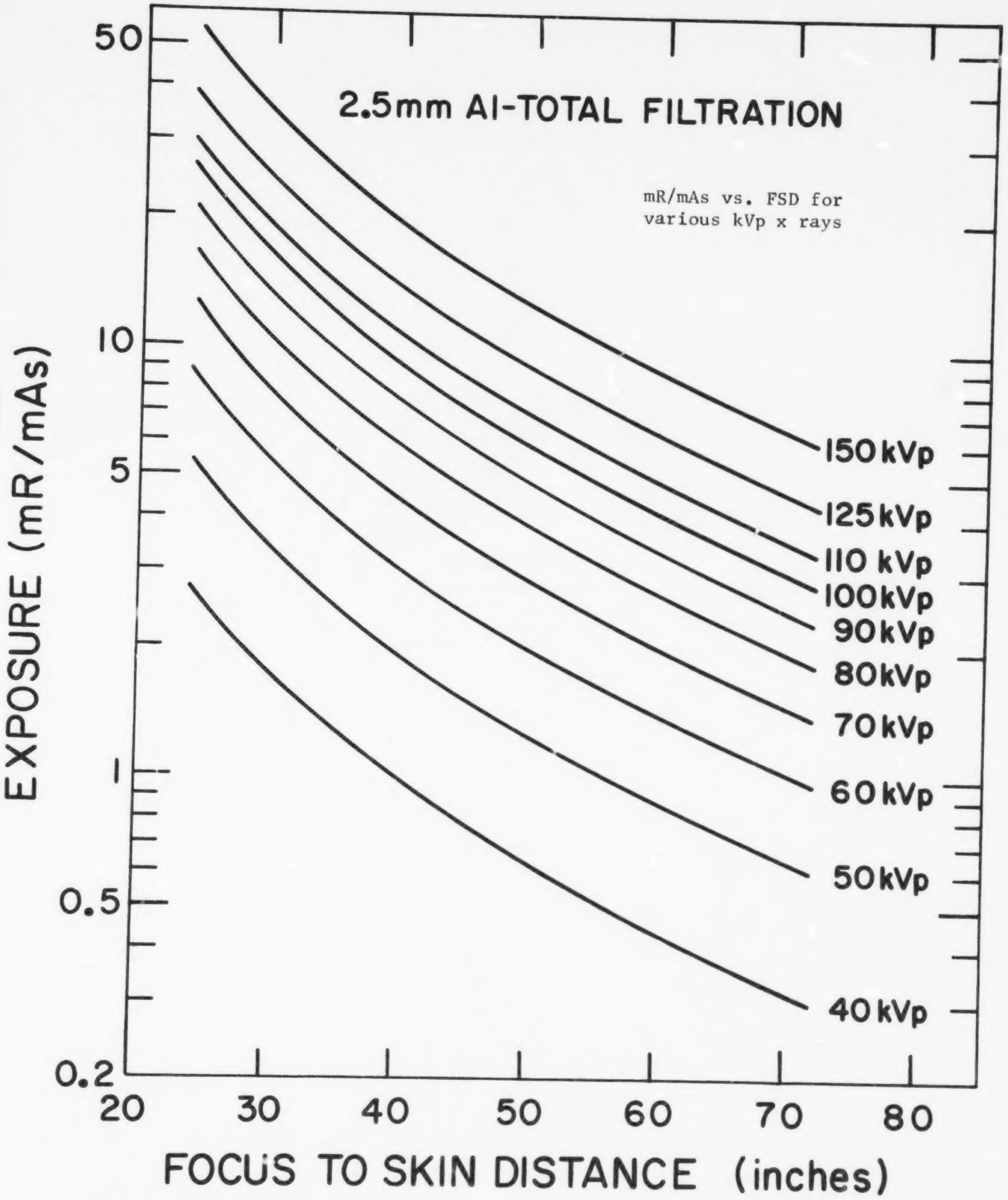
Total filtration (millimeters of Al equivalent)	Kilovolt peak								
	50	55	60	65	70	75	80	85	90
0.5	91.11	96.03	101.44	107.59	114.73	123.10	132.94	144.49	158.00
1.0	58.38	63.32	68.54	74.27	80.75	88.24	96.98	107.20	119.15
1.5	36.61	41.64	46.72	52.09	57.99	64.66	72.35	81.30	91.75
2.0	23.26	28.45	33.45	38.52	43.89	49.81	56.52	64.25	73.27
2.5	15.79	21.19	26.19	31.01	35.92	41.14	46.93	53.52	61.16
3.0	11.65	17.33	22.37	27.02	31.52	36.12	41.04	46.55	52.88
3.5	8.30	14.32	19.47	24.01	28.17	32.19	36.32	40.80	45.88
4.0	3.19	9.61	14.94	19.43	23.30	26.82	30.21	33.73	37.62
4.5	---	.67	6.24	10.73	14.39	17.46	20.18	22.80	25.56

TABLE 2.—*Mean milliroentgens per milliampere-second at 12 inches by kilovolt peak and filtration categories for nondental X-ray units*

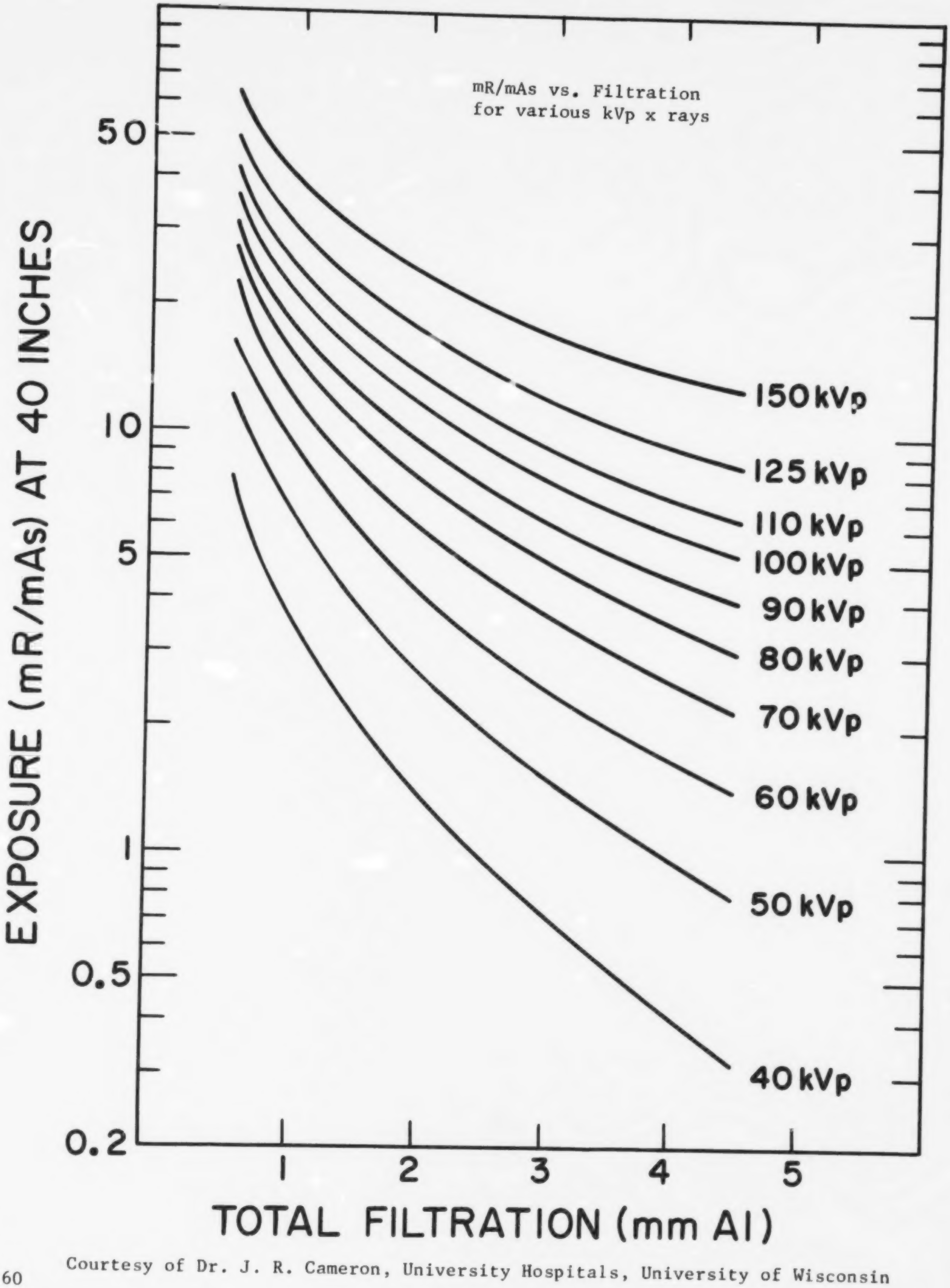
Total filtration (millimeters of Al equivalent)	Kilovolt peak					
	45	50	55	60	65	70
0.5	67.02	78.58	89.90	101.16	112.51	124.11
1.0	43.25	52.83	62.16	71.41	80.74	90.31
1.5	27.62	35.49	43.10	50.62	58.21	66.03
2.0	18.35	24.80	30.97	37.04	43.17	49.52
2.5	13.69	18.99	24.00	28.90	33.84	38.99
3.0	11.87	16.29	20.42	24.43	28.46	32.70
3.5	11.12	14.96	18.48	21.87	25.28	28.88
4.0	9.69	13.21	16.41	19.46	22.52	25.76
4.5	5.81	9.29	12.44	15.43	18.42	21.57

Total filtration (millimeters of Al equivalent)	Kilovolt peak—Continued					
	75	80	85	90	95	100
0.5	136.14	148.76	162.12	176.40	191.76	208.36
1.0	100.30	110.86	122.16	134.36	147.63	162.14
1.5	74.26	83.04	92.56	102.96	114.42	127.10
2.0	56.25	63.54	71.55	80.43	90.36	101.49
2.5	44.52	50.59	57.37	65.01	73.68	83.55
3.0	37.30	42.43	48.25	54.93	62.63	71.51
3.5	32.83	37.29	42.44	48.43	55.43	63.61
4.0	29.33	33.41	38.17	43.75	50.33	58.07
4.5	25.06	29.03	33.66	39.12	45.56	53.15

Tables from Population Exposure to X-Rays U.S. 1964, PHS No. 1519.



Courtesy of Dr. J. R. Cameron, University Hospitals, University of Wisconsin



Courtesy of Dr. J. R. Cameron, University Hospitals, University of Wisconsin

X-Ray Critical-Absorption and Emission Energies in kev

By **S. FINE** and **C. F. HENDEE**
Philips Laboratories
Irvington on Hudson, New York

Increased use of energy-proportional detectors for X-rays has created a need for a table of energy values of K and L absorption and emission series.

The table presented here includes all elements. Most values were obtained by a conversion to kev of tabulated experimental wavelength values (*1–3*); some are from previous energy-value compilations (*4, 5*). Where a choice existed, the value chosen was the one derived from later work. Certain values were determined by interpolation, using Moseley's law. (All this is annotated in footnotes.)

The conversion equations relating energy and wavelength used are (*6*)

$$E\ (\text{kev}) = (12.39644 \pm 0.00017)/\lambda(\text{Å})$$
$$= 12.39644/1.002020\ \lambda(\text{kX unit})$$

In computing values the number of places retained sufficed to maintain the uncertainty in the original source value. The values in the table have been listed uniformly to 1 ev. However, chemical form may shift absorption edges as much as 10–20 ev (*4, 5*).

To discover computational errors a fit was made to Moseley's law. In general the values were consistent, however there were a few irregularities due to the deviation of some input values (*1*). These were retained in the body of the table but a set of values calculated to fit better are footnoted.

* * *

The authors wish to express their appreciation to W. Parrish for helpful suggestions and to H. Kasper for performing the computation in connection with this work.

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X-Ray Critical-Absorption and Emission Energies in kev

Atomic Number	Element	*K series*					*L series*							
		K_{ab}	$K\beta_2$	$K\beta_1$	$K\alpha_1$	$K\alpha_2$	L_{Iab}	L_{IIab}	L_{IIIab}	$L\gamma_1$	$L\beta_2$	$L\beta_1$	$L\alpha_1$	$L\alpha_2$
1	Hydrogen	0.0136‡												
2	Helium	0.0246‡												
3	Lithium	0.055			0.052									
4	Beryllium	0.116§			0.110									
5	Boron	0.192†			0.185									
6	Carbon	0.283			0.282									
7	Nitrogen	0.399			0.392									
8	Oxygen	0.531			0.523									
9	Fluorine	0.687†			0.677									
10	Neon	0.874*			0.851§		0.048†	0.022†	0.022†					
11	Sodium	1.08*		1.067	1.041		0.055§	0.034§	0.034§					
12	Magnesium	1.303		1.297	1.254		0.063	0.050	0.049					
13	Aluminum	1.559		1.553	1.487	1.486	0.087	0.073**	0.072**					
14	Silicon	1.838		1.832	1.740	1.739	0.118*	0.099**	0.098**					
15	Phosphorus	2.142		2.136	2.015§	2.014§	0.153*	0.129§	0.128§					
16	Sulphur	2.470		2.464	2.308	2.306	0.193*	0.164**	0.163**					
17	Chlorine	2.819¶		2.815	2.622	2.621	0.238*	0.203§	0.202§					
18	Argon	3.203		3.192§	2.957	2.955	0.287*	0.247**	0.245**					
19	Potassium	3.607		3.589	3.313	3.310	0.341*	0.297**	0.294**					
20	Calcium	4.038		4.012	3.691	3.688	0.399*	0.352	0.349			0.344		0.341
21	Scandium	4.496		4.460	4.090	4.085	0.462*	0.411**	0.406**			0.399		0.395
22	Titanium	4.964		−4.931	4.510	4.504	0.530*	0.460**	0.454**			0.458		0.452
23	Vanadium	5.463		−5.427	4.952	4.944	0.604*	0.519**	0.512**			0.519		0.510
24	Chromium	5.988		−5.946	5.414	5.405	0.679*	0.583**	0.574**			0.581		0.571
25	Manganese	6.537		6.490	5.898	5.887	0.762*	0.650**	0.639**			0.647		0.636
26	Iron	7.111		7.057	6.403	6.390	0.849*	0.721**	0.708**			0.717		0.704
27	Cobalt	7.709		7.649	6.930	6.915	0.929*	0.794**	0.779**			0.790		0.775
28	Nickel	8.331	8.328	8.264	7.477	7.460	1.015*	0.871**	0.853**			0.866		0.849
29	Copper	8.980	8.976	8.904	8.047	8.027	1.100*	0.953	0.933			0.948		0.928
30	Zinc	9.660	9.657	9.571	8.638	8.615	1.200*	1.045	1.022			1.032		1.009

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Atomic Number	Element	K series					L series							
		K_{ab}	$K\beta_2$	$K\beta_1$	$K\alpha_1$	$K\alpha_2$	L_{Iab}	L_{IIab}	L_{IIIab}	$L\gamma_1$	$L\beta_2$	$L\beta_1$	$L\alpha_1$	$L\alpha_2$
31	Gallium	10.368	10.365	10.263	9.251	9.234	1.30*	1.134**	1.117**			1.122	1.096	
32	Germanium	11.103	11.100	10.981	9.885	9.854	1.42*	1.248**	1.217**			1.216	1.186	
33	Arsenic	11.863	11.863	11.725	10.543	10.507	1.529	1.359	1.323			1.317	1.282	
34	Selenium	12.652	12.651	12.495	11.221	11.181	1.652	1.473	1.434			1.419	1.379	
35	Bromine	13.475	13.465	13.290	11.923	11.877	1.794§	1.599**	1.552**			1.526	1.480	
36	Krypton	14.323	14.313	14.112	12.648	12.597	1.931§	1.727**	1.675**			1.638§	1.587**	
37	Rubidium	15.201	15.184	14.960	13.394	13.335	2.067	1.866	1.806			1.752	1.694	1.692
38	Strontium	16.106	16.083	15.834	14.164	14.097	2.221	2.008	1.941			1.872	1.806	1.805
39	Yttrium	17.037	17.011	16.736	14.957	14.882	2.369	2.154	2.079			1.996	1.922	1.920
40	Zirconium	17.998	17.969	17.666	15.774	15.690	2.547	2.305	2.220	2.302	2.219	2.124	2.042	2.040
41	Niobium	18.987	18.951	18.621	16.614	16.520	2.706	2.467**	2.374	2.462	2.367	2.257	2.166	2.163
42	Molybdenum	20.002	19.964	19.607	17.478	17.373	2.884	2.627	2.523	2.623	2.518	2.395	2.293	2.290
43	Technetium	21.054§	21.012§	−20.585¶	18.410¶	18.328¶	3.054§	2.795§	2.677§	2.792§	2.674§	2.538§	2.424§	2.420§
44	Ruthenium	22.118	22.072	21.655	19.278	19.149	3.236§	2.966	2.837	2.964	2.836	2.683	2.558	2.554
45	Rhodium	23.224	23.169	22.721	20.214	20.072	3.419	3.145	3.002	3.144	3.001	2.834	2.696	2.692
46	Palladium	24.347	24.297	23.816	21.175	21.018	3.617	3.329	3.172	3.328	3.172	2.990	2.838	2.833
47	Silver	25.517	25.454	24.942	22.162	21.988	3.810	3.528	3.352	3.519	3.348	3.151	2.984	2.978
48	Cadmium	26.712	26.641	26.093	23.172	22.982	4.019	3.727	3.538	3.716	3.528	3.316	3.133	3.127
49	Indium	27.928	27.859	27.274	24.207	24.000	4.237	3.939	3.729	3.920	3.713	3.487	3.287	3.279
50	Tin	29.190	29.106	28.483	25.270	25.042	4.464	4.157	3.928	4.131	3.904	3.662	3.444	3.435
51	Antimony	30.486	30.387	29.723	26.357	26.109	4.697	4.381	4.132	4.347	4.100	3.843	3.605	3.595
52	Tellurium	31.809	31.698	30.993	27.471	27.200	4.938	4.613	4.341	4.570	4.301	4.029	3.769	3.758
53	Iodine	33.164	33.016	32.292	28.610	28.315	5.190	4.856	4.559	4.800	4.507	4.220	3.937	3.926
54	Xenon	34.579	34.446¶	33.644	29.802¶	29.485¶	5.452	5.104	4.782	5.036§	4.720§	4.422§	4.111§	4.098§
55	Cesium	35.959	35.819	34.984	30.970	30.623	5.720	5.358	5.011	5.280	4.936	4.620	4.286	4.272
56	Barium	37.410	37.255	36.376	32.191	31.815	5.995	5.623	5.247	5.531	5.156	4.828	4.467	4.451
57	Lanthanum	38.931	38.728	37.799	33.440	33.033	6.283	5.894	5.489	5.789	5.384	5.043	4.651	4.635
58	Cerium	40.449	40.231	39.255	34.717	34.276	6.561	6.165†	5.729	6.052	5.613	5.262	4.840	4.823
59	Praseodymium	41.998	41.772	40.746	36.023	35.548	6.846	6.443	5.968	6.322	5.850	5.489	5.034	5.014
60	Neodymium	43.571	43.298¶	42.269	37.359	36.845	7.144	6.727	6.215	6.602	6.090	5.722	5.230	5.208
61	Promethium	45.207§	44.955§	−43.945¶	38.649¶	38.160¶	7.448§	7.018§	6.466§	6.891§	6.336§	5.956	5.431	5.408§
62	Samarium	46.846	46.553¶	45.400	40.124	39.523	7.754	7.281¶	6.721	7.180	6.587	6.206	5.636	5.609
63	Europium	48.515	48.241	47.027	41.529	40.877	8.069	7.624	6.983	7.478	6.842	6.456	5.846	5.816
64	Gadolinium	50.229	49.961	48.718	42.983	42.280	8.393	7.940	7.252	7.788	7.102	6.714	6.059	6.027
65	Terbium	51.998	51.737	50.391	44.470	43.737	8.724	8.258	7.519	8.104	7.368	6.979	6.275	6.241
66	Dysprosium	53.789	53.491	52.178	45.985	45.193	9.083	8.621¶	7.850¶	8.418	7.638	7.249	6.495	6.457
67	Holmium	55.615	55.292**	53.934§	47.528	46.686	9.411	8.920	8.074	8.748	7.912	7.528	6.720	6.680
68	Erbium	57.483	57.088	55.690	49.099	48.205	9.776	9.263	8.364	9.089	8.188	7.810	6.948	6.904
69	Thulium	59.335¶	58.969**	57.576¶	50.730	49.762	10.144	9.628	8.652	9.424	8.472	8.103	7.181	7.135
70	Ytterbium	61.303	60.959	59.352	52.360	51.326	10.486	9.977	8.943	9.779	8.758	8.401	7.414	7.367
71	Lutecium	63.304	62.946	61.282	54.063	52.959	10.867	10.345	9.241	10.142	9.048	8.708	7.654	7.604
72	Hafnium	65.313	64.936	63.209	55.757	54.579	11.264	10.734	9.556	10.514	9.346	9.021	7.898	7.843
73	Tantalum	67.400	66.999	65.210	57.524	56.270	11.676	11.130	9.876	10.892	9.649	9.341	8.145	8.087
74	Tungsten	69.508	69.090	67.233	59.310	57.973	12.090	11.535	10.198	11.283	9.959	9.670	8.396	8.333
75	Rhenium	71.662	71.220	69.298	61.131	59.707	12.522	11.955	10.531	11.684	10.273	10.008	8.651	8.584
76	Osmium	73.860	73.393	71.404	62.991	61.477	12.965	12.383	10.869	12.094	10.596	10.354	8.910	8.840
77	Iridium	76.097	75.605	73.549	64.886	63.278	13.413	12.819	11.211	12.509	10.918	10.706	9.173	9.098
78	Platinum	78.379	77.866	75.736	66.820	65.111	13.873	13.268	11.559	12.939	11.249	11.069	9.441	9.360
79	Gold	80.713	80.165	77.968	68.794	66.980	14.353	13.733	11.919	13.379	11.582	11.439	9.711	9.625
80	Mercury	83.106	82.526	80.258	70.821	68.894	14.841	14.212	12.285	13.828	11.923	11.823	9.987	9.896
81	Thallium	85.517	84.904	82.558	72.860	70.820	15.346	14.697	12.657	14.288	12.268	12.210	10.266	10.170
82	Lead	88.001	87.343	84.922	74.957	72.794	15.870	15.207	13.044	14.762	12.620	12.611	10.549	10.448
83	Bismuth	90.521	89.833	87.335	77.097	74.805	16.393	15.716	13.424	15.244	12.977	13.021	10.836	10.729
84	Polonium	93.112	92.386	89.809	79.296	76.868	16.935	16.244	13.817	15.740	13.338	13.441	11.128	11.014
85	Astatine	95.740	94.976	92.319	81.525	78.956	17.490	16.784	14.215	16.248	13.705	13.873	11.424	11.304
86	Radon	98.418	97.616	94.877	83.800	81.080	18.058	17.387	14.618	16.768	14.077	14.316	11.724	11.597
87	Francium	101.147	100.305	97.483	86.119	83.243	18.638	17.904	15.028	17.301	14.459	14.770	12.029	11.894
88	Radium	103.927	103.048	100.136	88.485	85.446	19.233	18.481	15.442	17.845	14.839	15.233	12.338	12.194
89	Actinium	106.759	105.838	102.846	90.894	87.681	19.842	19.078	15.865	18.405	15.227	15.712	12.650	12.499
90	Thorium	109.630	108.671	105.592	93.334	89.942	20.460	19.688	16.296	18.977	15.620	16.200	12.966	12.808
91	Protactinium	112.581	111.575	108.408	95.851	92.271	21.102	20.311	16.731	19.559	16.022	16.700	13.291	13.120
92	Uranium	115.591	114.549	111.289	98.428	94.648	21.753	20.943	17.163	20.163	16.425	17.218	13.613	13.438
93	Neptunium	118.619	117.533	114.181	101.005	97.023	22.417	21.596	17.614	20.774	16.837	17.740	13.945	13.758
94	Plutonium	121.720	120.592	117.146	103.653	99.457	23.097	22.262	18.066	21.401	17.254	18.278	14.279	14.082
95	Americium	124.876	123.706	120.163	106.351	101.932	23.793	22.944	18.525	22.042	17.677	18.829	14.618	14.411
96	Curium	128.088	126.875	123.235	109.098	104.448	24.503	23.640	18.990	22.699	18.106	19.393	14.961	14.743
97	Berkelium	131.357	130.101	126.362	111.896	107.023	25.230	24.352	19.461	23.370	18.540	19.971	15.309	15.079
98	Californium	134.683	133.383	129.544	114.745	109.603	25.971	25.080	19.938	24.056	18.980	20.562	15.661	15.420
99		138.067	136.724	132.781	117.646	112.244	26.729	25.824	20.422	24.758	19.426	21.166	16.018	15.764
100		141.510	140.122	136.075	120.598	114.926	27.503	26.584	20.912	25.475	19.879	21.785	16.379	16.113

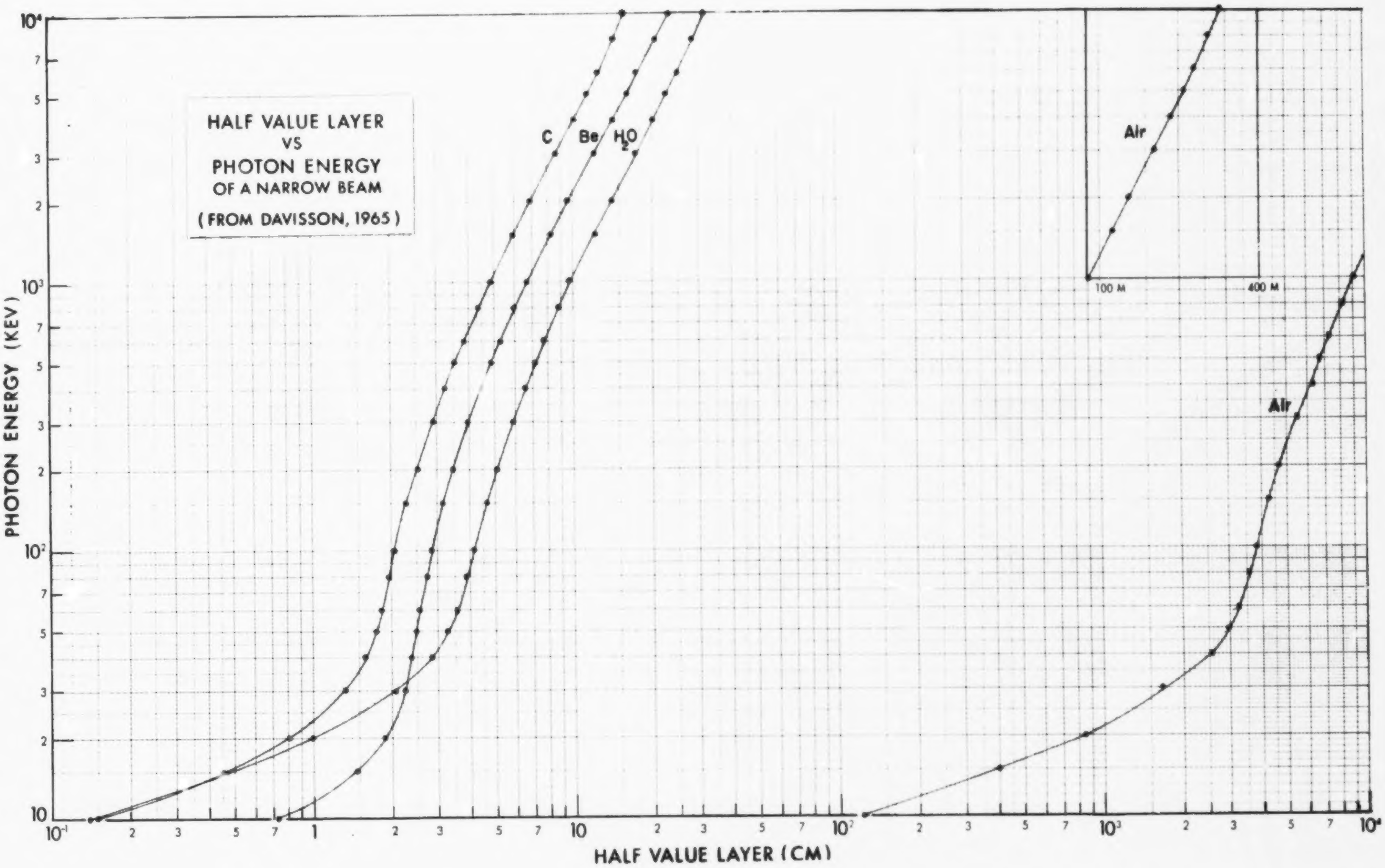
For $Z \leq 69$, values without symbols are derived from (*1*). Values prefixed with a − sign are $K\beta_{1+3}$.

For $Z \geq 70$, absorption-edge values are from (*4*) in the case of $Z = 70$–83, 88, 90, and 92; remaining absorption edges to $Z = 100$ are obtained from these by least-squares quadratic fitting. All emission values for $Z \geq 70$ are derived from the preceding absorption edges, and others based on (*4*), using the transition relations $K\alpha_1 = K_{ab} - L_{III}$, $K\alpha_2 = K_{ab} - L_{II}$, $K\beta_1 = K_{ab} - M_{III}$, etc.

* Obtained from R. D. Hill, E. L. Church, J. W. Mihelich (*5*). † Derived from Compton and Allison (*2*). ‡ Derived from C. E. Moore (*3*).

¶ Values derived from Cauchois and Hulubei (*1*) which deviate from the Moseley law. Better-fitting values are: $Z = 17$, $K_{ab} = 2.826$; $Z = 43$, $K\alpha_1 = 18.370$, $K\alpha_2 = 18.250$, $K\beta_1 = 20.612$; $Z = 54$, $K\alpha_1 = 29.779$, $K\alpha_2 = 29.463$, $K\beta_2 = 34.398$; $Z = 60$, $K\beta_2 = 43.349$; $Z = 61$, $K\alpha_1 = 38.726$, $K\alpha_2 = 38.180$, $K\beta_1 = 43.811$; $Z = 62$, $K\beta_2 = 46.581$, $L_{II} = 7.312$; $Z = 66$, $L_{II} = 8.591$, $L_{III} = 7.790$; $Z = 69$, $K_{ab} = 59.382$, $K\beta_1 = 57.487$.

§ Calculated by method of least squares. ** Calculated by transition relations.

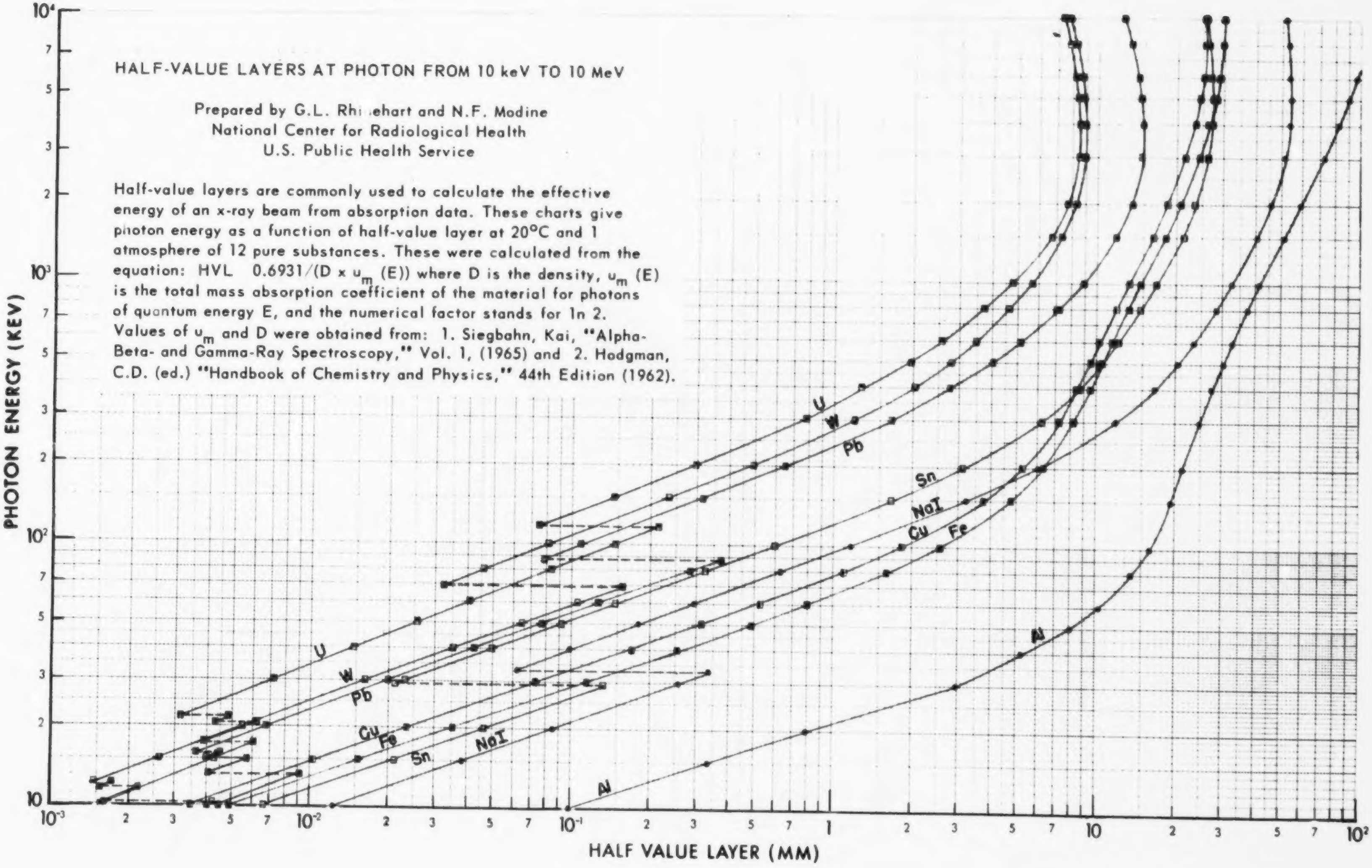


HALF VALUE LAYER
VS
PHOTON ENERGY
OF A NARROW BEAM
(FROM DAVISSON, 1965)

HALF-VALUE LAYERS AT PHOTON FROM 10 keV TO 10 MeV

Prepared by G.L. Rhinehart and N.F. Modine
National Center for Radiological Health
U.S. Public Health Service

Half-value layers are commonly used to calculate the effective energy of an x-ray beam from absorption data. These charts give photon energy as a function of half-value layer at 20°C and 1 atmosphere of 12 pure substances. These were calculated from the equation: HVL $0.6931/(D \times u_m(E))$ where D is the density, $u_m(E)$ is the total mass absorption coefficient of the material for photons of quantum energy E, and the numerical factor stands for ln 2. Values of u_m and D were obtained from: 1. Siegbahn, Kai, "Alpha- Beta- and Gamma-Ray Spectroscopy," Vol. 1, (1965) and 2. Hodgman, C.D. (ed.) "Handbook of Chemistry and Physics," 44th Edition (1962).



MEDICAL X RAY FILM SPEEDS*

Film (Screen Films)	Slow Screen (Radelin UD)	Medium Screen (Patterson Par-Speed)	Fast Screen (Ilford Fast)	Contrast Factor†
Ansco Fine-X	350	890	1570	2.6
Ansco Hi-Speed	400	1000	1780	2.4
Dupont Cronex I	280	700	1230	3.0
Dupont Cronex II	360	910	1600	3.4
Dupont Cronex III	560	1430	2520	2.9
Ferrania Radio N	350	880	1560	2.7
Gevaert Curix	260	670	1190	2.6
Gevaert Curix Rapid	470	1190	2110	2.8
Gevaert Curix Spec.	180	460	820	2.6
Ilford Red Seal	350	880	1550	2.7
Ilford Standard	220	560	1000	2.8
Kodak Blue Brand	320	820	1460	2.8
Kodak Royal Blue	610	1550	2740	3.0

(Non-Screen Films)	Without Screen			Contrast Factor
Ansco No Screen	47	--------------	--------------	2.2
Ferrania Simplex	25	--------------	--------------	2.0
Gevaert Osray	46	--------------	--------------	2.2
Ilford Ilfex	39	--------------	--------------	2.5
Kodak No Screen	51	--------------	--------------	2.5

*Speed = 1/R, where R is the exposure in roentgens required to obtain a film density of 1.0 under specified development conditions. Film exposed with x-ray beam of 4 mm Al HVL and developed 3 minutes in Kodak Liquid Developer at 20° C.

†The slope of the H & D curve (plot of film density vs. log exposure) at a film density of 1.0. The contrast factor is generally independent of screen type and HVL of exposing beam except when film is used without screens.

The information on pages 165 through 167 is taken from "Some Physical Factors Affecting Radiographic Image Quality: Their Theoretical Basis and Measurement," by Lloyd M. Bates (PHS Publication No. 999-RH-38) August 1969.

MEDICAL X RAY SCREEN SPEEDS*

Screen	Slow Film (Gevaert Curix Spec.)	Medium Film (Kodak Blue Brand)	Fast Film (Kodak Royal Blue)
Ansco High Speed	610	1080	2040
Ansco Medium Speed	490	880	1660
Auer Flash-speed	730	1300	2440
Buck A	440	780	1480
Buck AA	550	990	1860
Buck AAA	610	1090	2050
Ilford Fast	820	1460	2740
Ilford Standard	420	760	1430
Patterson Detail	280	500	930
Patterson Hi-speed	680	1220	2300
Patterson Par-speed	460	820	1550
Radelin HR	230	410	780
Radelin T	440	790	1480
Radelin TF	720	1290	2440
Radelin UD	180	320	610
Wolf Rapid	490	870	1640
Wolf Ultra	560	1000	1880
Without screen†	6	13	22

*Speed = 1/R, where R is the exposure in roentgens required to obtain a film density of 1.0 under specified development conditions. Films exposed with x-ray beam of 4 mm Al HVL and developed 3 minutes in Kodak Liquid Developer at 20° C.

†Screen-type film used.

VARIATION OF MEDICAL X RAY FILM SPEED WITH HVL*

Screen	Film	HVL		
		2 mm Al	4 mm Al	6 mm Al
Slow (Radelin UD)	Medium (Kodak Blue Brand)	260	320	370
Medium (Patterson Par-speed)	Medium (Kodak Blue Brand)	630	820	940
Fast (Ilford Fast)	Medium (Kodak Blue Brand)	980	1460	1770
None	Medium (Kodak Blue Brand)	11	13	13
None	Fast (Kodak No Screen)	42	51	58

*Speed = 1/R, where R is the exposure in roentgens required to obtain a film density of 1.0 under specified development conditions. Films developed 3 minutes in Kodak Liquid Developer at 20° C.

PERCENTAGE BACKSCATTER TABLES

X-ray exposure is measured in air at a given distance from the x-ray tube. When a beam of x rays is incident on a patient or other object, the exposure rate at the surface will be increased by x rays scattered back to the detector by the patient or the tabletop. The percentage backscatter is a measure of the increase in exposure rate and is defined as the increase in exposure rate at the surface of the patient compared to the exposure rate at the same point in air:

$$\text{Percentage Backscatter} = \frac{X_s - X_a}{X_a} \times 100$$

where: X_s = exposure rate at the surface
X_a = exposure rate at the same distance in air.

The following tables give percentage backscatter for circular and rectangular fields of various sizes and at various HVL's with open-ended treatment cones.

(a) CIRCULAR FIELDS

Half Value Layer	*Area cm²*	*10*	*16*	*20*	*25*	*35*	*50*	*61*	*80*	*100*	*150*	*200*	*300*	*400*
mm Al	*radius cm*	*1.78*	*2.26*	*2.52*	*2.82*	*3.34*	*3.99*	*4.51*	*5.05*	*5.64*	*6.77*	*7.98*	*9.75*	*11.3*
1.0		10.8	12.8	13.8	14.8	16.4	17.9	18.9	19.7	20.5	21.8	22.9		
2.0		11.8	14.3	15.4	16.8	19.0	21.1	22.5	23.8	25.0	26.6	27.9		
3.0		13.4	16.4	17.9	19.4	21.7	24.0	25.6	27.0	28.3	30.2	31.8		
4.0		14.1	17.4	19.0	20.8	23.6	26.5	28.3	29.9	31.4	33.4	35.0		
mm Cu														
0.25		17.4	20.5	22.0	23.7	26.3	29.2	31.2	33.0	34.8	37.4	39.5	42.4	45.0
0.5		18.6	22.0	23.5	25.4	28.2	31.4	33.6	35.7	37.6	40.6	43.0	46.3	49.2
1.0		15.0	18.4	20.0	22.1	25.2	28.8	31.4	33.8	36.0	39.3	42.0	45.8	49.0
1.5		13.8	16.9	18.4	20.1	23.0	26.2	28.4	30.6	32.7	36.1	39.1	42.8	46.0
2.0		11.9	14.5	16.0	17.6	20.1	23.0	25.0	26.9	28.8	32.0	34.8	38.5	41.8
3.0		9.8	12.0	13.0	14.4	16.4	18.8	20.5	22.2	23.8	26.6	28.9	31.6	34.0
4.0		7.6	9.4	10.4	11.4	13.2	15.2	16.8	18.2	19.7	22.0	24.0	26.4	28.0

(b) RECTANGULAR FIELDS CM × CM

Half Value Layer mm Cu	*Field Size (cm × cm)* *4×4*	*4×6*	*4×8*	*4×10*	*4×15*	*4×20*	*6×6*	*6×8*	*6×10*	*6×15*	*6×20*
0.5	21.4	24.4	26.1	27.2	28.5	29.2	28.3	30.6	32.1	34.0	35.0
1.0	18.0	21.1	23.0	24.3	25.8	26.6	25.2	27.9	29.7	31.8	33.0
1.5	16.6	19.3	21.0	22.2	23.7	24.5	23.0	25.3	26.9	29.1	30.3
2.0	14.4	16.9	18.4	19.4	20.8	21.6	20.1	22.2	23.7	25.7	26.9
3.0	11.6	13.7	14.9	15.8	17.0	17.6	16.4	18.2	19.4	21.1	22.1

	8×8	*8×10*	*8×15*	*8×20*	*10×10*	*10×15*	*10×20*	*15×15*	*15×20*	*20×20*
0.5	33.4	35.2	37.6	39.0	37.3	40.1	41.8	43.9	46.2	48.9
1.0	31.1	33.3	36.0	37.5	35.7	38.9	40.7	43.0	45.6	48.7
1.5	28.2	30.2	33.0	34.5	32.4	35.7	37.6	40.0	42.6	45.7
2.0	24.8	26.5	29.2	30.7	28.6	31.7	33.5	35.8	38.4	41.5
3.0	20.4	21.9	24.1	25.3	23.7	26.2	27.7	29.6	31.5	33.7

Tables reprinted from: Johns, H. E., The Physics of Radiology, 2nd Ed., 1964.

DEPTH DOSE TABLES

"Percentage depth dose" is the ratio of radiation dose at some depth (d) below the surface of the patient or phantom (D_d) to the dose at the surface (D_s):

$$\text{Percentage Depth Dose} = \frac{D_d}{D_s} \times 100.$$

At high energies (e.g., ^{60}Co), the maximum dose occurs at some point below the surface. In this case the percentage depth dose is defined as the ratio of absorbed dose at some depth d (D_d) to the maximum dose (D_m):

$$\text{Percentage Depth Dose} = \frac{D_d}{D_m} \times 100.$$

The following tables give percentage depth doses for various field sizes and exposure parameters.

HVL 1.0 mm Al. (Approximately 70 kvp With Inherent Filtration)

	Area (cm²)	*0*	*3.1*	*7.0*	*12.5*	*28.3*	*50*	*100*
	Diam. (cm)	*0*	*2*	*3*	*4*	*6*	*8*	*11.3*
	Depth (cm)							
	0	100	100	100	100	100	100	100
	0.5	61	74	79	81	84	86	87
	1	42	56	61	63	66	67	69
FSD 15 cm	2	23	32	36	39	41	42	44
	3	13	19	22	24	26	27	29
	4	8	12	13	15	17	19	20
	8	2	2	3	3	4	4	5
	0	100	100	100	100	100	100	100
	0.5	62	75	80	82	84	86	88
	1	44	58	63	65	67	68	70
FSD 20 cm	2	24	34	38	41	43	44	45
	3	14	20	23	25	28	29	31
	4	9	13	15	16	18	20	21
	8	2	3	3	4	4	5	6
	0	100	100	100	100	100	100	100
	0.5	63	76	81	83	85	88	89
	1	45	60	64	66	68	70	71
FSD 30 cm	2	25	36	40	42	44	46	48
	3	16	22	25	27	30	31	33
	4	10	14	16	18	20	22	23
	8	2	3	4	4	5	6	7

HVL 2.0 mm Al. (Approximately 120 kvp With Inherent Filtration)

	0	100	100	100	100	100	100	100
	0.5	71	82	85	87	88	89	90
	1	52	65	69	72	74	76	77
FSD 15 cm	2	31	42	47	49	53	55	56
	3	20	28	32	34	38	40	42
	4	14	19	22	24	27	30	32
	8	3	5	6	7	9	10	11
	0	100	100	100	100	100	100	100
	0.5	72	83	86	88	89	90	91
	1	54	66	71	73	76	77	78
FSD 20 cm	2	33	44	49	51	55	57	58
	3	22	30	34	36	40	42	44
	4	15	21	24	26	30	32	34
	8	4	6	7	8	10	11	13
	0	100	100	100	100	100	100	100
	0.5	73	84	87	88	89	91	92
	1	55	68	73	74	77	79	80
FSD 30 cm	2	35	47	51	54	57	60	61
	3	24	33	37	39	43	45	47
	4	17	23	27	29	32	35	37
	8	5	7	8	9	11	13	15

Tables reprinted from: Johns, H. E., The Physics of Radiology, 2nd Ed., 1964.

DEPTH DOSE--Continued

HVL 3.0 MM AL. (APPROXIMATELY 120 KVP 1 MM AL. FILTER)

	Area (cm²)	*0*	*3.1*	*7.0*	*12.5*	*28.3*	*50*	*100*
	Diam. (cm)	*0*	*2*	*3*	*4*	*6*	*8*	*11.3*
	Depth (cm)							
FSD 15 cm	0	100	100	100	100	100	100	100
	0.5	75	85	87	88	89	90	90
	1	58	70	74	76	77	78	80
	2	37	48	53	56	59	60	62
	3	24	33	37	41	45	46	48
	4	17	23	27	30	34	35	37
	8	4	6	8	9	11	13	14
FSD 20 cm	0	100	100	100	100	100	100	100
	0.5	76	86	88	89	90	91	91
	1	60	72	75	77	79	80	81
	2	39	51	55	58	62	63	65
	3	27	35	40	43	47	49	51
	4	19	25	29	32	36	38	40
	8	5	7	9	10	12	14	16
FSD 30 cm	0	100	100	100	100	100	100	100
	0.5	77	86	88	90	91	92	92
	1	62	74	77	79	81	82	83
	2	41	54	58	61	65	66	67
	3	29	39	43	46	51	53	55
	4	21	28	32	35	40	42	44
	8	6	9	10	12	14	17	19

HVL 4.0 MM AL. (APPROXIMATELY 140 KVP 2.0 MM AL. FILTER)

FSD 15 cm	0	100	100	100	100	100	100	100
	0.5	78	87	89	90	91	92	93
	1	62	74	77	79	80	81	84
	2	40	52	56	59	62	63	67
	3	27	37	41	44	47	49	53
	4	19	26	30	32	36	38	42
	8	5	8	9	10	12	14	17
FSD 20 cm	0	100	100	100	100	100	100	100
	0.5	79	88	89	90	92	93	94
	1	63	76	78	80	82	83	86
	2	43	55	59	62	64	66	70
	3	30	40	44	46	49	52	56
	4	21	29	32	35	38	41	45
	8	6	9	10	12	14	16	19
FSD 30 cm	0	100	100	100	100	100	100	100
	0.5	80	90	91	92	93	94	95
	1	65	78	81	82	83	84	87
	2	45	58	62	65	68	69	73
	3	32	43	47	50	54	56	60
	4	24	32	36	38	42	45	49
	8	7	11	12	14	17	19	22

DEPTH DOSE--Continued

HVL 0.5 mm Cu FSD 40 cm

Depth in cm	*Area of Field in Square Centimetres* 0	20	35	50	80	100	150	200	400
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	74.6	91.7	93.6	94.7	96.4	97.0	98.0	98.6	99.3
2	56.5	78.1	81.5	83.4	86.0	86.9	88.8	89.9	91.9
3	43.2	64.8	68.9	71.6	74.6	76.0	78.4	80.0	83.4
4	33.3	52.9	57.7	60.5	64.2	65.6	68.1	69.7	73.9
5	25.8	43.3	47.8	50.9	54.6	56.2	59.0	61.0	65.1
6	20.0	35.4	39.3	42.4	46.0	47.5	50.5	52.8	57.0
7	15.5	28.9	32.6	35.6	38.8	40.1	43.2	45.4	49.8
8	12.1	23.7	27.1	29.5	32.5	34.0	36.8	39.0	43.5
9	9.4	19.4	22.3	24.7	27.3	28.7	31.4	33.4	37.5
10	7.4	16.1	18.4	20.5	23.0	24.3	26.6	28.5	32.7
11	5.8	13.2	15.3	17.0	19.3	20.5	22.5	24.3	28.2
12	4.6	10.8	12.8	14.3	16.3	17.4	19.2	20.8	24.5
13	3.7	8.8	10.7	12.0	13.7	14.7	16.3	17.6	21.1
14	2.9	7.3	8.9	10.0	11.5	12.3	13.9	15.3	18.3
15	2.4	6.0	7.4	8.3	9.7	10.4	11.8	13.0	15.7
16	1.9	4.9	6.1	6.9	8.2	8.8	10.1	11.1	13.6
17	1.5	4.1	5.1	5.8	6.9	7.4	8.6	9.6	11.7
18	1.2	3.4	4.2	4.8	5.8	6.3	7.3	8.2	10.1
19	1.0	2.8	3.5	4.0	4.9	5.3	6.2	7.0	8.7
20	.8	2.3	2.9	3.4	4.1	4.5	5.3	5.9	7.5

HVL 0.5 mm Cu FSD 50 cm

Depth in cm	*Area of Field in Square Centimetres* 0	20	35	50	80	100	150	200	400
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	75.3	92.3	94.3	95.4	97.1	97.7	98.7	99.3	100.0
2	55.7	79.0	82.5	84.4	87.0	88.0	89.9	91.0	93.0
3	44.5	66.0	70.2	72.9	76.0	77.4	79.8	81.5	84.9
4	34.5	54.3	59.2	62.1	65.9	67.3	69.9	71.6	75.9
5	27.0	44.7	49.3	52.5	56.3	58.0	60.9	62.9	67.2
6	21.1	36.7	40.8	44.0	47.7	49.3	52.4	54.8	59.1
7	16.5	30.1	34.0	37.1	40.4	41.8	45.0	47.3	51.9
8	13.0	24.8	28.3	30.8	34.0	35.5	38.5	40.8	45.2
9	10.1	20.4	23.4	25.9	28.6	30.1	32.9	35.0	39.4
10	8.0	16.9	19.4	21.6	24.2	25.6	28.0	30.0	34.4
11	6.3	13.9	16.2	18.0	20.4	21.6	23.8	25.7	29.8
12	5.1	11.4	13.5	15.1	17.2	18.4	20.3	22.0	25.9
13	4.1	9.4	11.3	12.7	14.5	15.6	17.3	18.7	22.4
14	3.3	7.7	9.4	10.6	12.2	13.1	14.8	16.2	19.4
15	2.6	6.4	7.8	8.8	10.3	11.1	12.6	13.8	16.7
16	2.1	5.3	6.5	7.4	8.7	9.4	10.8	11.8	14.5
17	1.7	4.3	5.4	6.2	7.3	7.9	9.2	10.2	12.5
18	1.4	3.6	4.5	5.2	6.2	6.7	7.8	8.7	10.8
19	1.1	3.0	3.8	4.3	5.2	5.7	6.6	7.5	9.3
20	.9	2.4	3.1	3.6	4.4	4.8	5.6	6.4	8.1

DEPTH DOSE--Continued

HVL 1.0 MM CU FSD 40 CM

Depth in cm	*Area of Field in Square Centimetres* 0	20	35	50	80	100	150	200	400
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	78.3	93.5	96.2	97.5	99.2	100.1	101.3	101.9	102.3
2	61.7	82.1	87.2	89.0	92.0	93.0	94.7	95.6	97.1
3	49.0	71.1	75.9	79.0	83.1	84.7	87.1	88.9	91.4
4	39.0	60.5	65.5	68.8	73.2	75.2	78.2	80.3	84.2
5	31.1	50.9	55.8	59.3	63.9	65.6	69.1	71.3	75.5
6	25.0	42.8	47.4	50.7	55.1	57.1	60.3	62.6	67.4
7	20.0	35.8	40.1	43.2	47.4	49.3	52.7	55.1	59.9
8	16.1	29.8	33.7	36.5	40.5	42.6	45.7	48.1	53.1
9	13.0	24.9	28.5	31.0	34.7	36.7	39.9	41.9	46.9
10	10.4	20.8	24.9	26.4	29.6	31.4	34.4	36.4	41.5
11	8.4	17.4	20.3	22.4	25.3	27.0	29.6	31.6	36.4
12	6.7	14.6	17.1	19.0	21.5	23.1	25.6	27.5	31.8
13	5.4	12.2	14.4	16.0	18.4	19.7	22.0	23.9	27.8
14	4.4	10.2	12.2	13.6	15.7	16.9	19.0	20.7	24.3
15	3.5	8.5	10.2	11.5	13.5	14.5	16.3	17.8	21.3
16	2.8	7.1	8.6	9.7	11.5	12.4	14.0	15.4	18.6
17	2.3	6.0	7.2	8.3	9.8	10.6	12.1	13.3	16.3
18	1.9	5.0	6.1	7.0	8.3	9.0	10.4	11.5	14.3
19	1.5	4.2	5.2	5.9	7.1	7.8	8.9	9.9	12.5
20	1.2	3.5	4.4	5.0	6.1	6.7	7.7	8.5	10.9

HVL 1.0 MM CU FSD 50 CM

Depth in cm	*Area of Field in Square Centimetres* 0	20	35	50	80	100	150	200	400
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	79.0	94.2	96.9	98.2	99.9	100.8	102.0	102.6	103.0
2	63.0	83.2	88.3	90.2	93.2	94.2	95.9	96.9	98.4
3	50.5	72.5	77.4	80.5	84.7	86.3	88.8	90.6	93.5
4	40.5	62.0	67.2	70.6	75.1	77.1	80.2	82.4	86.4
5	32.5	52.5	57.5	61.1	65.9	67.6	71.2	73.5	77.8
6	26.3	44.4	49.1	52.5	57.1	59.2	62.5	64.9	69.8
7	21.3	37.3	41.8	45.0	49.4	51.4	54.8	57.3	62.3
8	17.3	31.2	35.2	38.2	42.4	44.6	47.8	50.3	55.5
9	14.0	26.1	29.9	32.5	36.4	38.5	41.8	43.9	49.3
10	11.3	21.9	25.2	27.8	31.2	33.1	36.2	38.3	43.6
11	9.1	18.3	21.4	23.7	26.7	28.5	31.3	33.4	38.5
12	7.4	15.4	18.2	20.1	22.8	24.4	27.1	29.1	33.8
13	5.9	12.9	15.3	17.0	19.5	20.9	23.4	25.3	29.5
14	4.8	10.8	13.0	14.4	16.7	17.9	20.2	21.9	25.8
15	3.9	9.1	10.8	12.2	14.3	15.4	17.4	18.9	22.7
16	3.2	7.6	9.1	10.3	12.2	13.2	14.9	16.4	19.8
17	2.6	6.4	7.7	8.8	10.4	11.3	12.9	14.2	17.3
18	2.1	5.3	6.5	7.4	8.9	9.6	11.1	12.3	15.2
19	1.7	4.5	5.5	6.3	7.6	8.3	9.5	10.6	13.3
20	1.4	3.7	4.7	5.4	6.5	7.1	8.2	9.1	11.6

DEPTH DOSE--Continued

HVL 1.0 mm Cu FSD 60 cm

Depth	*Area of Field in Square Centimetres*								
in cm	*0*	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	79.6	94.8	97.5	98.8	100.5	101.4	102.6	103.2	103.6
2	63.8	84.2	89.4	91.3	94.3	95.3	97.1	98.1	99.6
3	51.5	73.8	78.8	81.9	86.2	87.9	90.4	92.2	95.2
4	41.5	63.4	68.7	72.2	76.8	78.9	82.0	84.3	88.4
5	33.5	54.0	59.0	62.7	67.6	69.4	73.0	75.3	79.7
6	27.4	45.6	50.5	54.0	58.7	60.9	64.3	66.7	71.8
7	22.2	38.5	43.0	46.4	50.9	53.0	56.5	59.1	64.2
8	18.1	32.2	36.4	39.5	43.8	46.1	49.5	52.0	57.3
9	14.6	27.0	30.9	33.6	37.7	39.8	43.2	45.4	51.0
10	11.8	22.7	26.2	28.8	32.4	34.3	37.5	39.7	45.2
11	9.7	19.0	22.2	24.6	27.7	29.6	32.5	34.7	40.0
12	7.8	16.0	18.8	20.8	23.7	25.4	28.2	30.3	35.2
13	6.4	13.4	15.9	17.7	20.3	21.8	24.4	26.4	30.8
14	5.2	11.3	13.5	15.0	17.4	18.7	21.0	22.9	27.0
15	4.2	9.5	11.3	12.7	15.0	16.1	18.1	19.8	23.7
16	3.4	8.0	9.6	10.7	12.8	13.8	15.6	17.2	20.8
17	2.8	6.7	8.1	9.2	10.9	11.9	13.5	14.9	18.2
18	2.3	5.6	6.9	7.8	9.3	10.1	11.7	12.8	15.9
19	1.9	4.7	5.8	6.6	8.0	8.7	10.0	11.2	14.0
20	1.6	3.9	4.9	5.6	6.8	7.5	8.6	9.6	12.2

HVL 1.0 mm Cu FSD 80 cm

Depth	*Area of Field in Square Centimetres*								
in cm	*0*	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	80.4	95.3	98.1	99.4	101.1	102.0	103.2	103.8	104.2
2	64.9	85.4	90.6	92.5	95.5	96.6	98.3	99.3	100.9
3	52.6	75.3	80.3	83.4	87.7	89.4	91.9	93.8	96.8
4	42.7	65.0	70.4	73.8	78.6	80.6	83.8	86.1	90.3
5	34.8	55.4	60.7	64.4	69.5	71.3	75.0	77.4	81.9
6	28.6	47.2	52.2	55.8	60.7	62.9	66.4	68.9	74.1
7	23.4	40.0	44.7	48.2	52.9	54.9	58.6	61.3	66.6
8	19.2	33.6	38.1	41.1	45.6	47.9	51.4	54.0	59.6
9	15.7	28.3	32.4	35.2	39.5	41.6	45.1	47.5	53.2
10	12.9	23.9	27.5	30.3	34.0	36.0	39.4	41.6	47.3
11	10.5	20.1	23.4	25.9	29.2	31.1	34.2	36.5	42.0
12	8.6	17.0	19.8	22.1	25.1	26.8	29.7	31.9	37.0
13	7.0	14.3	16.8	18.8	21.5	23.0	25.7	27.8	32.4
14	5.7	12.0	14.3	16.0	18.4	19.8	22.3	24.2	28.5
15	4.7	10.1	12.1	13.6	15.8	17.1	19.3	21.0	25.2
16	3.9	8.5	10.2	11.5	13.6	14.7	16.6	18.3	22.1
17	3.2	7.2	8.7	9.8	11.7	12.6	14.4	15.9	19.4
18	2.6	6.0	7.4	8.4	10.0	10.8	12.5	13.8	17.0
19	2.2	5.1	6.2	7.1	8.6	9.3	10.7	11.9	14.9
20	1.8	4.2	5.3	6.1	7.4	8.0	9.3	10.4	13.1

HVL 1.5 MM Cu FSD 40 CM

Depth in cm	*Area of Field in Square Centimetres*								
	0	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	80.1	94.3	96.3	98.0	98.9	99.7	100.7	101.5	102.0
2	63.9	83.8	87.4	89.3	92.0	93.0	94.8	95.9	98.0
3	51.2	72.4	76.9	79.8	83.3	85.1	87.6	89.2	92.3
4	41.5	61.7	66.5	69.6	74.0	76.0	78.9	80.8	81.7
5	33.5	52.3	57.0	60.4	64.8	66.7	70.0	72.1	76.6
6	27.0	44.3	48.6	52.0	56.4	58.9	62.1	64.4	69.2
7	21.8	37.4	41.8	44.7	49.1	51.3	54.4	56.9	62.3
8	17.6	31.5	35.4	38.2	42.7	44.4	47.6	50.0	55.8
9	14.2	26.4	30.0	32.6	36.8	38.3	41.7	44.0	49.6
10	11.4	22.2	25.5	27.9	31.5	33.2	36.4	38.3	44.0
11	9.3	18.7	21.6	23.7	27.1	28.5	31.5	33.4	38.7
12	7.5	15.8	18.4	20.3	23.3	24.6	27.4	29.2	34.1
13	6.1	13.2	15.6	17.3	20.0	21.3	23.8	25.4	30.1
14	5.0	11.1	13.2	14.8	17.2	18.4	20.7	22.3	26.3
15	4.1	9.4	11.2	12.6	14.8	15.8	17.9	19.5	23.2
16	3.3	7.9	9.6	10.8	12.7	13.6	15.6	17.0	20.3
17	2.7	6.7	8.1	9.2	11.0	11.8	13.6	14.9	17.9
18	2.2	5.6	6.9	7.9	9.5	10.2	11.9	13.1	15.7
19	1.8	4.8	5.9	6.8	8.1	8.8	10.3	11.5	13.8
20	1.5	4.0	5.0	5.8	7.0	7.6	8.9	10.1	12.1

HVL 1.5 MM Cu FSD 50 CM

Depth in cm	*Area of Field in Square Centimetres*								
	0	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	80.8	95.0	97.0	98.0	99.6	100.4	101.5	102.2	102.7
2	65.2	84.9	88.6	90.5	93.2	94.2	96.0	97.2	99.3
3	52.7	73.9	78.5	81.4	85.0	86.8	89.4	91.0	94.2
4	43.0	63.3	68.3	71.5	76.0	78.0	81.0	83.0	87.0
5	35.0	53.9	58.8	62.3	66.8	68.8	72.1	74.3	79.0
6	28.4	45.9	50.3	53.8	58.4	61.0	64.3	66.7	71.6
7	23.2	38.9	43.4	46.4	51.0	53.3	56.5	59.1	64.7
8	18.8	32.8	36.9	39.8	44.5	46.3	49.6	52.1	58.2
9	15.3	27.6	31.4	34.1	38.5	40.1	43.6	46.0	51.9
10	12.4	23.3	26.8	29.3	33.1	34.8	38.2	40.2	46.2
11	10.2	19.7	22.8	25.0	28.6	30.0	33.2	35.2	40.8
12	8.3	16.7	19.4	21.4	24.6	26.0	28.9	30.8	36.0
13	6.7	14.0	16.5	18.3	21.2	22.5	25.2	26.9	31.8
14	5.5	11.8	14.0	15.7	18.2	19.5	21.9	23.6	27.9
15	4.5	10.0	11.9	13.4	15.7	16.8	19.0	20.7	24.6
16	3.7	8.4	10.2	11.5	13.5	14.5	16.6	18.1	21.6
17	3.1	7.1	8.7	9.8	11.7	12.5	14.4	15.8	19.0
18	2.5	6.0	7.4	8.4	10.1	10.8	12.6	13.9	16.7
19	2.1	5.1	6.3	7.2	8.6	9.4	10.9	12.2	14.7
20	1.7	4.3	5.3	6.2	7.4	8.1	9.5	10.7	12.9

HVL 1.5 mm Cu FSD 60 cm

Depth	*Area of Field in Square Centimetres*								
in cm	*0*	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	81.4	95.6	97.6	98.6	100.2	101.0	102.1	102.8	103.3
2	66.0	85.8	89.6	91.5	94.2	95.2	97.1	98.3	100.4
3	53.7	75.0	79.7	82.6	86.3	88.1	90.7	92.4	95.6
4	44.0	64.6	69.7	72.9	77.5	79.6	82.6	84.7	88.7
5	36.1	55.2	60.2	63.8	68.4	70.5	73.8	76.1	80.9
6	29.4	47.1	51.7	55.3	60.0	62.6	66.0	68.5	73.5
7	24.2	40.1	44.7	47.8	52.5	54.9	58.2	60.9	66.6
8	19.7	33.8	38.1	41.1	45.9	47.8	51.2	53.8	60.1
9	16.1	28.6	32.5	35.3	39.8	41.5	45.1	47.6	53.7
10	13.1	24.2	27.8	30.4	34.3	36.1	39.6	41.7	47.9
11	10.8	20.5	23.7	26.0	29.7	31.2	34.5	36.6	42.4
12	8.8	17.4	20.2	22.3	25.6	27.0	30.1	32.0	37.4
13	7.2	14.6	17.2	19.1	22.1	23.4	26.3	28.0	33.1
14	5.9	12.3	14.6	16.4	19.0	20.4	22.9	24.6	29.1
15	4.9	10.5	12.4	14.0	16.4	17.5	19.9	21.6	25.7
16	4.0	8.8	10.7	12.0	14.1	15.2	17.4	19.0	22.6
17	3.4	7.5	9.1	10.3	12.3	13.1	15.1	16.6	19.9
18	2.8	6.3	7.7	8.8	10.6	11.3	13.2	14.6	17.5
19	2.3	5.3	6.6	7.6	9.1	9.8	11.5	12.8	15.4
20	1.9	4.5	5.6	6.5	7.8	8.5	10.0	11.3	13.6

HVL 1.5 mm Cu FSD 80 cm

Depth	*Area of Field in Square Centimetres*								
in cm	*0*	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	82.3	96.3	98.3	99.3	100.9	101.7	102.7	103.4	103.8
2	67.2	87.1	90.9	92.8	95.4	96.4	98.1	99.3	101.5
3	54.9	76.7	81.4	84.3	88.0	89.8	92.4	94.0	97.2
4	45.4	66.4	71.5	74.9	79.4	81.4	84.6	86.6	90.7
5	37.5	57.0	62.1	65.7	70.5	72.5	75.0	78.2	83.0
6	30.8	48.9	53.5	57.2	62.1	64.8	68.2	70.8	75.8
7	25.5	41.7	46.5	49.7	54.6	57.0	60.4	63.1	69.1
8	20.9	35.4	39.8	42.9	47.9	49.8	53.3	56.0	62.5
9	17.2	29.9	34.1	36.9	41.7	43.3	47.1	49.7	56.0
10	14.1	25.4	29.2	31.9	36.0	37.8	41.5	43.7	50.1
11	11.8	21.6	25.0	27.3	31.3	32.7	36.2	38.4	44.5
12	9.6	18.4	21.3	23.5	27.0	28.5	31.6	33.7	39.4
13	7.9	15.5	18.2	20.2	23.3	24.8	27.7	29.6	34.9
14	6.6	13.1	15.5	17.4	20.1	21.5	24.2	26.0	30.7
15	5.4	11.2	13.2	14.9	17.4	18.6	21.0	22.9	27.2
16	4.5	9.5	11.4	12.8	15.0	16.1	18.4	20.1	24.0
17	3.7	8.0	9.7	11.0	13.1	14.0	16.1	17.6	21.1
18	3.1	6.8	8.3	9.4	11.3	12.1	14.1	15.6	18.7
19	2.6	5.7	7.1	8.1	9.7	10.5	12.3	13.7	16.5
20	2.2	4.9	6.0	7.0	8.4	9.1	10.7	12.1	14.5

DEPTH DOSE--Continued

HVL 2.0 mm Cu FSD 50 cm

Depth	*Area of Field in Square Centimetres*								
in cm	*0*	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	81.4	95.0	96.9	97.9	99.1	99.9	101.0	101.6	102.4
2	66.5	85.5	88.5	90.3	92.7	93.8	95.4	96.6	99.0
3	54.0	74.3	78.6	81.3	84.8	86.3	88.8	90.5	93.7
4	44.2	63.9	68.7	71.8	75.8	77.6	80.7	82.8	87.0
5	36.2	54.9	59.5	62.8	67.0	68.8	71.9	74.2	79.2
6	29.6	46.5	51.2	54.5	58.8	61.0	64.2	66.5	71.8
7	24.3	39.6	44.0	47.2	51.5	53.4	57.0	59.2	64.8
8	19.9	33.5	37.7	40.8	44.8	46.8	50.3	52.7	58.5
9	16.4	28.4	32.4	35.2	39.2	40.9	44.4	46.5	52.4
10	13.4	24.0	27.7	30.3	33.9	35.7	38.9	41.3	46.7
11	11.1	20.4	23.7	26.0	29.4	31.0	34.0	36.3	41.6
12	9.1	17.2	20.2	22.3	25.4	27.0	29.7	31.8	36.9
13	7.5	14.7	17.3	19.2	21.9	23.4	26.0	28.0	32.7
14	6.2	12.5	14.8	16.5	19.0	20.3	22.8	24.7	28.9
15	5.1	10.6	12.6	14.1	16.4	17.7	19.9	21.7	25.5
16	4.2	8.9	10.8	12.1	14.2	15.3	17.4	19.1	22.6
17	3.5	7.6	9.2	10.4	12.3	13.3	15.2	16.8	20.0
18	2.9	6.5	7.8	8.9	10.7	11.6	13.3	14.8	17.7
19	2.4	5.5	6.7	7.7	9.2	10.0	11.6	13.0	15.6
20	2.0	4.7	5.7	6.6	7.9	8.7	10.2	11.4	13.8

HVL 2.0 mm Cu FSD 60 cm

Depth	*Area of Field in Square Centimetres*								
in cm	*0*	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	82.0	95.5	97.4	98.4	99.9	100.4	101.5	102.1	102.9
2	67.3	86.4	89.5	91.2	93.6	94.7	96.4	97.6	100.0
3	55.0	75.5	79.9	82.6	86.2	87.7	90.2	91.9	95.2
4	45.2	65.3	70.1	73.3	77.3	79.2	82.3	84.5	88.7
5	37.3	56.3	61.0	64.4	68.7	70.5	73.7	76.1	81.1
6	30.7	47.9	52.6	56.0	60.4	62.5	65.9	68.2	73.7
7	25.3	40.9	45.4	48.7	53.1	55.0	58.7	61.0	66.6
8	20.9	34.7	39.0	42.2	46.3	48.3	52.0	54.4	60.2
9	17.3	29.5	33.5	36.4	40.6	42.3	46.0	48.1	54.0
10	14.2	25.0	28.7	31.4	35.2	37.0	40.3	42.7	48.4
11	11.8	21.2	24.6	27.0	30.5	32.3	35.3	37.6	43.1
12	9.7	18.1	21.0	23.2	26.4	28.1	30.9	33.1	38.3
13	8.0	15.4	18.0	20.0	22.9	24.4	27.1	29.1	34.0
14	6.6	13.1	15.5	17.2	19.8	21.3	23.8	25.8	30.1
15	5.5	11.1	13.2	14.8	17.1	18.5	20.8	22.7	26.6
16	4.6	9.4	11.3	12.7	14.8	16.0	18.2	20.0	23.6
17	3.8	8.0	9.6	10.9	12.9	13.9	15.9	17.6	21.0
18	3.2	6.8	8.2	9.4	11.2	12.1	13.9	15.5	18.6
19	2.6	5.8	7.0	8.1	9.7	10.5	12.2	13.7	16.4
20	2.2	4.9	6.0	6.9	8.4	9.1	10.7	12.0	14.5

HVL 2.0 MM CU FSD 80 CM

Depth in cm	*Area of Field in Square Centimetres*								
	0	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	82.9	96.1	98.0	99.0	100.5	101.0	102.1	102.7	103.4
2	68.5	87.6	90.6	92.5	94.8	96.0	97.6	98.8	101.2
3	56.3	77.1	81.4	84.1	87.8	89.1	91.7	93.5	96.7
4	46.6	67.1	71.9	75.2	79.2	81.0	84.2	86.4	90.7
5	38.7	58.1	62.9	66.3	70.7	72.6	75.8	78.2	83.2
6	32.1	49.7	54.5	58.0	62.6	64.8	68.1	70.6	76.0
7	26.7	42.6	47.3	50.6	55.2	57.1	60.9	63.2	69.1
8	22.1	36.3	40.7	44.1	48.3	50.4	54.1	56.6	62.8
9	18.4	30.9	35.2	38.2	42.3	44.3	48.0	50.3	56.6
10	15.3	26.3	30.2	33.0	36.9	38.8	42.2	44.7	50.7
11	12.8	22.5	26.0	28.5	32.1	33.9	37.1	39.6	45.3
12	10.6	19.1	22.3	24.5	27.9	29.6	32.5	34.8	40.4
13	8.8	16.3	19.1	21.2	24.1	25.8	28.6	30.8	35.9
14	7.3	13.9	16.4	18.3	21.0	22.5	25.2	27.3	31.8
15	6.1	11.8	14.0	15.7	18.2	19.6	22.0	24.0	28.2
16	5.1	10.1	12.1	13.5	15.8	17.0	19.4	21.3	25.1
17	4.3	8.6	10.3	11.7	13.7	14.9	17.0	18.8	22.3
18	3.6	7.3	8.8	10.1	12.0	13.0	14.9	16.6	19.8
19	3.0	6.3	7.6	8.7	10.3	11.3	13.1	14.6	17.5
20	2.5	5.3	6.5	7.4	9.0	9.8	11.5	12.9	15.6

HVL 2.0 MM CU FSD 100 CM

Depth in cm	*Area of Field in Square Centimetres*								
	0	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	83.1	96.6	98.5	99.5	101.0	101.4	102.5	103.1	103.8
2	69.2	88.4	91.4	93.2	95.6	96.6	98.3	99.5	101.9
3	57.2	78.2	82.4	85.1	88.7	90.2	92.8	94.5	97.7
4	47.7	68.2	73.1	76.3	80.3	82.2	85.4	87.5	91.9
5	39.7	59.3	64.1	67.5	72.0	73.8	77.1	79.5	84.6
6	33.0	50.9	55.9	59.3	63.9	66.2	69.5	72.0	77.5
7	27.6	43.8	48.4	51.9	56.5	58.5	62.4	64.7	70.7
8	23.0	37.4	41.9	45.3	49.6	51.8	55.6	58.0	64.4
9	19.2	32.0	36.4	39.4	43.8	45.6	49.5	51.7	58.2
10	15.9	27.3	31.3	34.2	38.1	40.1	43.6	46.2	52.3
11	13.4	23.4	27.0	29.5	33.3	35.1	38.4	40.9	46.8
12	11.1	19.8	23.2	25.5	29.0	30.7	33.7	36.1	41.8
13	9.3	17.0	20.0	22.1	25.1	26.8	29.7	32.0	37.2
14	7.8	14.5	17.2	19.1	21.9	23.4	26.2	28.4	33.1
15	6.5	12.5	14.7	16.4	19.0	20.5	23.0	25.0	29.4
16	5.4	10.6	12.7	14.2	16.6	17.8	20.2	22.1	26.1
17	4.6	9.0	10.8	12.3	14.4	15.6	17.7	19.6	23.3
18	3.8	7.7	9.3	10.6	12.6	13.6	15.6	17.3	20.7
19	3.2	6.6	8.0	9.1	10.9	11.8	13.7	15.3	18.3
20	2.7	5.7	6.9	7.8	9.5	10.3	12.1	13.5	16.3

DEPTH DOSE--Continued

HVL 3.0 MM Cu FSD 50 CM

Depth in cm	*Area of Field in Square Centimetres*								
	0	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	82.3	94.7	96.5	97.4	98.6	99.0	100.0	100.5	101.4
2	68.0	85.8	88.2	89.8	91.7	92.7	94.3	95.4	97.6
3	56.2	75.0	78.8	81.0	84.1	85.4	87.5	89.2	92.4
4	46.4	64.8	69.1	71.8	75.4	77.0	79.8	81.8	85.9
5	38.6	56.0	60.0	63.0	66.8	68.6	71.6	73.9	78.4
6	32.0	47.7	52.0	54.9	58.8	60.9	64.0	66.4	71.0
7	26.5	40.8	44.8	47.8	51.8	54.0	56.9	59.4	64.4
8	22.0	34.9	38.7	41.5	45.5	47.6	50.4	53.0	58.2
9	18.4	29.7	33.3	36.0	39.8	41.7	44.6	47.2	52.2
10	15.4	25.3	28.6	31.1	34.7	36.6	39.5	41.8	46.8
11	12.8	21.7	24.6	26.9	30.3	32.0	34.8	37.2	41.9
12	10.7	18.5	21.1	23.2	26.4	27.9	30.6	32.7	37.3
13	9.0	15.7	18.2	20.0	22.9	24.4	26.9	28.8	33.3
14	7.5	13.4	15.7	17.3	19.9	21.2	23.6	25.4	29.5
15	6.3	11.5	13.4	15.0	17.3	18.5	20.7	22.4	26.3
16	5.3	9.8	11.5	12.9	15.0	16.1	18.2	19.7	23.4
17	4.5	8.4	9.9	11.2	13.1	14.0	15.9	17.4	20.8
18	3.7	7.2	8.5	9.6	11.4	12.2	14.0	15.4	18.5
19	3.1	6.1	7.3	8.3	9.9	10.7	12.3	13.6	16.5
20	2.6	5.2	6.3	7.2	8.6	9.3	10.8	11.9	14.6

HVL 3.0 MM Cu FSD 60 CM

Depth in cm	*Area of Field in Square Centimetres*								
	0	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	82.9	95.3	97.1	98.0	99.2	99.5	100.6	101.1	102.0
2	68.8	86.7	89.2	90.8	92.7	93.7	95.3	96.4	98.7
3	57.3	76.2	80.1	82.3	85.4	86.8	88.9	90.6	93.9
4	47.5	66.1	70.5	73.2	76.8	78.5	81.3	83.3	87.4
5	39.8	57.5	61.4	64.5	68.3	70.2	73.2	75.5	80.1
6	33.2	49.1	53.4	56.4	60.3	62.5	65.6	68.1	72.8
7	27.6	42.2	46.2	49.3	53.3	55.6	58.6	61.1	66.2
8	23.1	36.2	40.0	42.9	47.0	49.1	52.0	54.7	60.0
9	19.4	30.9	34.6	37.3	41.2	43.2	46.2	48.9	54.0
10	16.3	26.4	29.8	32.3	36.1	38.0	41.0	43.3	48.5
11	13.6	22.7	25.7	28.0	31.5	33.3	36.2	38.6	43.4
12	11.4	19.4	22.1	24.2	27.5	29.1	31.9	34.1	38.8
13	9.6	16.5	19.1	20.9	24.0	25.5	28.1	30.1	34.8
14	8.1	14.2	16.5	18.1	20.9	22.2	24.7	26.6	30.9
15	6.8	12.2	14.2	15.7	18.2	19.5	21.8	23.6	27.6
16	5.8	10.4	12.2	13.6	15.8	17.0	19.2	20.8	24.6
17	4.9	8.9	10.5	11.8	13.9	14.8	16.8	18.4	21.9
18	4.1	7.6	9.1	10.2	12.1	12.9	14.8	16.3	19.6
19	3.5	6.5	7.9	8.9	10.5	11.4	13.1	14.4	17.5
20	2.9	5.6	6.8	7.7	9.2	9.9	11.5	12.7	15.6

HVL 3.0 MM Cu FSD 80 CM

Depth in cm	Area of Field in Square Centimetres								
	0	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	83.8	95.9	97.8	98.6	99.7	100.1	101.1	101.6	102.5
2	70.0	88.0	90.3	92.0	93.9	94.8	96.5	97.6	99.7
3	58.6	77.9	81.7	83.8	86.9	88.2	90.4	92.1	95.4
4	49.0	68.1	72.3	75.2	78.7	80.4	83.3	85.3	89.5
5	41.3	59.5	63.4	66.5	70.4	72.3	75.3	77.7	82.3
6	34.7	51.1	55.5	58.6	62.6	64.8	68.0	70.5	75.1
7	29.2	44.1	48.3	51.4	55.5	57.8	60.9	63.6	68.9
8	24.5	38.1	42.0	44.9	49.1	51.4	54.4	57.1	62.6
9	20.7	32.7	36.5	39.2	43.3	45.3	48.4	51.2	56.4
10	17.5	28.1	31.5	34.1	38.0	40.0	43.1	45.7	50.9
11	14.7	24.2	27.3	29.7	33.4	35.2	38.2	40.7	45.8
12	12.5	20.8	23.6	25.8	29.2	30.9	33.8	36.1	41.0
13	10.5	17.8	20.4	22.2	25.5	27.1	29.9	31.9	36.8
14	8.9	15.3	17.7	19.4	22.3	23.7	26.3	28.2	32.8
15	7.6	13.2	15.2	16.9	19.4	20.8	23.2	25.0	29.4
16	6.4	11.3	13.2	14.7	17.0	18.2	20.5	22.1	26.3
17	5.4	9.7	11.4	12.8	14.9	15.9	18.1	19.7	23.5
18	4.6	8.3	9.9	11.1	13.0	13.9	15.9	17.5	21.0
19	3.9	7.2	8.5	9.6	11.4	12.3	14.1	15.5	18.8
20	3.3	6.2	7.4	8.4	9.9	10.7	12.4	13.7	16.7

HVL 3.0 MM Cu FSD 100 CM

Depth in cm	Area of Field in Square Centimetres								
	0	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	84.0	96.4	98.1	99.0	100.1	100.5	101.5	101.9	102.8
2	70.7	88.8	91.1	92.7	94.5	95.5	97.0	98.2	100.3
3	59.6	79.0	82.7	84.8	87.9	89.2	91.4	93.0	96.3
4	50.1	69.3	73.5	76.3	79.8	81.5	84.4	86.4	90.6
5	42.4	60.8	64.7	67.8	71.7	73.6	76.7	79.1	83.7
6	35.7	52.4	56.8	59.9	63.9	66.1	69.3	71.8	76.6
7	30.1	45.5	49.6	52.8	56.9	59.3	62.3	65.0	70.3
8	25.4	39.3	43.4	46.3	50.6	52.8	55.8	58.6	64.1
9	21.6	33.9	37.7	40.6	44.7	46.7	49.8	52.6	58.0
10	18.3	29.2	32.7	35.4	39.3	41.4	44.5	47.0	52.4
11	15.4	25.2	28.4	30.9	34.6	36.5	39.5	42.1	47.3
12	13.1	21.7	24.6	26.9	30.4	32.1	35.0	37.4	42.4
13	11.1	18.6	21.3	23.4	26.6	28.2	31.0	33.1	38.0
14	9.5	16.1	18.5	20.4	23.3	24.7	27.4	29.4	34.0
15	8.1	13.8	16.0	17.8	20.4	21.7	24.2	26.1	30.5
16	6.9	11.9	13.9	15.4	17.8	19.0	21.4	23.1	27.3
17	5.8	10.3	12.1	13.5	15.6	16.7	18.9	20.5	24.4
18	5.0	8.9	10.5	11.7	13.7	14.6	16.7	18.2	21.9
19	4.2	7.6	9.2	10.2	12.0	12.9	14.7	16.2	19.6
20	3.6	6.6	7.9	8.9	10.5	11.3	13.0	14.3	17.5

HVL 4.0 MM CU FSD 50 CM

Depth in cm	*Area of Field in Square Centimetres*								
	0	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	83.1	94.1	96.0	96.8	97.7	98.0	98.8	99.3	[illegible]
2	69.3	85.9	87.8	89.1	90.8	91.6	93.0	93.9	96.0
3	57.8	75.6	78.8	80.7	83.3	84.3	86.2	87.6	90.1
4	48.2	65.5	69.5	71.8	75.0	76.4	78.9	80.5	84.2
5	40.7	56.6	60.4	63.2	66.6	68.2	71.2	73.4	77.1
6	34.3	48.5	52.7	55.5	58.9	60.8	63.8	66.1	70.2
7	28.9	41.6	45.6	48.4	51.8	53.7	56.8	59.4	63.8
8	24.4	35.7	39.5	42.0	45.5	47.3	50.5	53.1	57.8
9	20.5	30.6	34.0	36.5	39.8	41.6	44.8	47.3	51.8
10	17.3	26.3	29.4	31.6	35.0	36.7	39.7	42.0	46.6
11	14.6	22.6	25.4	27.4	30.6	32.3	35.1	37.4	41.8
12	12.4	19.4	21.9	23.7	26.8	28.4	30.9	33.1	37.5
13	10.5	16.7	19.0	20.6	23.4	24.9	27.3	29.2	33.6
14	8.9	14.3	16.4	17.9	20.4	21.8	24.1	25.8	30.0
15	7.5	12.3	14.1	15.5	17.8	19.0	21.2	22.8	26.7
16	6.4	10.6	12.2	13.5	15.6	16.7	18.7	20.1	23.8
17	5.4	9.4	10.6	11.7	13.6	14.6	16.4	17.7	21.2
18	4.6	7.8	9.1	10.2	11.8	12.8	14.4	15.7	18.9
19	4.0	6.7	7.9	8.8	10.3	11.2	12.6	13.8	16.9
20	3.4	5.8	6.8	7.7	9.0	9.7	11.1	12.2	15.1

HVL 4.0 MM CU FSD 80 CM

Depth in cm	*Area of Field in Square Centimetres*								
	0	*20*	*35*	*50*	*80*	*100*	*150*	*200*	*400*
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	84.6	95.6	97.2	97.9	98.8	99.1	99.8	100.3	101.0
2	71.4	88.0	89.7	91.1	92.8	93.6	95.0	95.9	97.9
3	60.2	78.5	81.5	83.4	86.0	87.0	88.9	90.4	93.2
4	50.9	68.8	72.7	75.0	78.2	79.7	82.2	83.9	87.5
5	43.5	60.2	63.9	66.7	70.2	71.9	74.9	77.1	80.9
6	37.2	52.2	56.3	59.2	62.7	64.8	67.8	70.1	74.2
7	31.7	45.3	49.2	52.1	55.7	57.8	60.9	63.6	67.9
8	27.1	39.3	43.1	45.7	49.4	51.3	54.6	57.3	62.1
9	23.1	34.0	37.5	40.1	43.6	45.4	48.8	51.5	56.0
10	19.7	29.5	32.7	35.0	38.6	40.4	43.6	46.1	50.8
11	16.8	25.6	28.5	30.6	34.0	35.8	38.8	41.3	45.9
12	14.4	22.2	24.8	26.7	29.9	31.6	34.4	36.8	41.4
13	12.3	19.3	21.6	23.4	26.4	27.9	30.6	32.7	37.4
14	10.5	16.6	18.8	20.4	23.1	24.7	27.2	29.1	33.6
15	9.0	14.4	16.3	17.8	20.3	21.6	24.0	[illegible]	30.1
16	7.7	12.5	14.2	15.6	17.8	19.1	21.3	23.0	27.0
17	6.6	10.8	12.4	13.7	15.7	16.8	18.9	20.3	24.2
18	5.7	9.4	10.8	12.0	13.8	14.8	16.7	18.1	21.7
19	4.9	8.1	9.4	10.5	12.1	13.1	14.8	16.1	19.5
20	4.2	7.0	8.2	9.1	10.6	11.5	13.1	14.3	17.6

COBALT 60 RADIATION
AVERAGE PHOTON ENERGY 1.25 MEV HVL 11 MM Pb SSD 50 CM

Depth in cm	*Area of Field in Square Centimetres*					
	0	*20*	*50*	*100*	*200*	*400*
0.5	100.0	100.0	100.0	100.0	100.0	100.0
1	94.6	96.2	97.0	97.5	97.6	97.7
2	85.2	89.2	90.6	91.4	91.8	92.1
3	76.8	82.3	84.2	85.4	86.1	86.8
4	69.3	75.7	78.2	79.6	80.6	81.6
5	62.6	69.5	72.4	74.0	75.3	76.6
6	56.4	63.7	66.8	68.6	70.2	71.8
7	51.0	58.3	61.4	63.4	65.3	67.1
8	46.1	53.3	56.4	58.6	60.7	62.7
9	41.7	48.7	51.7	53.9	56.2	58.6
10	37.8	44.5	47.4	49.7	52.2	54.9
11	34.3	40.6	43.5	45.8	48.4	51.2
12	31.1	37.1	40.0	42.2	45.0	47.8
13	28.2	33.9	36.7	39.0	41.7	44.7
14	25.6	31.0	33.7	36.0	38.7	41.7
15	23.3	28.4	30.9	33.2	36.0	39.0
16	21.1	26.0	28.4	30.6	33.4	36.5
17	19.3	23.8	26.1	28.3	31.1	34.2
18	17.5	21.8	24.0	26.2	28.9	32.0
19	15.9	19.9	22.2	24.2	26.9	29.9
20	14.5	18.2	20.3	22.4	25.0	28.1

COBALT 60 SSD 60 CM

Depth in cm	*Area of Field in Square Centimetres*					
	0	*20*	*50*	*100*	*200*	*400*
0.5	100.0	100.0	100.0	100.0	100.0	100.0
1	95.0	96.7	97.1	97.8	97.9	98.1
2	86.0	90.1	91.2	92.2	92.6	93.0
3	77.9	83.7	85.4	86.6	87.4	88.0
4	70.7	77.6	79.7	81.2	82.3	83.2
5	64.2	71.7	74.2	75.9	77.3	78.4
6	58.3	66.1	68.9	70.7	72.4	73.7
7	53.0	60.8	63.7	65.7	67.6	69.2
8	48.2	55.8	58.8	60.9	63.0	65.0
9	43.9	51.2	54.2	56.4	58.6	60.9
10	39.9	46.9	49.9	52.2	54.5	57.1
11	36.3	43.0	46.0	48.3	50.7	53.4
12	33.1	39.4	42.4	44.7	47.2	50.0
13	30.2	36.1	39.1	41.4	44.0	47.0
14	27.5	33.1	36.0	38.3	41.0	44.0
15	25.1	30.4	33.2	35.5	38.2	41.2
16	22.9	27.9	30.6	32.9	35.6	38.6
17	20.9	25.7	28.2	30.5	33.2	36.2
18	19.1	23.7	26.0	28.3	31.0	34.1
19	17.4	21.8	24.0	26.2	28.9	32.0
20	15.9	20.0	22.1	24.2	27.0	30.0

COBALT 60 SSD 80 CM

Depth in cm	*Area of Field in Square Centimetres* *0*	*20*	*50*	*100*	*200*	*400*
0.5	100.0	100.0	100.0	100.0	100.0	100.0
1	95.4	97.0	97.7	98.2	98.1	98.5
2	87.1	91.0	92.5	93.4	93.7	94.0
3	79.5	85.3	87.2	88.4	89.0	89.6
4	72.7	79.6	82.0	83.4	84.4	85.2
5	66.5	74.1	76.9	78.5	79.9	80.8
6	60.8	68.9	71.8	73.7	75.2	76.4
7	55.6	63.8	66.8	68.9	70.7	72.1
8	50.9	58.9	62.1	64.2	66.3	68.0
9	46.6	54.3	57.5	59.8	62.1	64.1
10	42.7	50.1	53.3	55.7	58.1	60.3
11	39.2	46.2	49.4	51.8	54.3	56.7
12	35.9	42.6	45.8	48.2	50.8	53.3
13	32.9	39.3	42.4	44.9	47.6	50.1
14	30.2	36.3	39.3	41.8	44.5	47.1
15	27.7	33.5	36.4	38.9	41.8	44.3
16	25.4	31.0	33.8	36.2	39.0	41.7
17	23.3	28.7	31.3	33.8	36.5	39.2
18	21.4	26.5	29.0	31.4	34.2	36.9
19	19.6	24.5	27.0	29.3	32.0	34.7
20	18.0	22.6	25.0	27.3	30.0	32.7

COBALT 60 SSD 100 CM

Depth in cm	*Area of Field in Square Centimetres* *0*	*20*	*50*	*100*	*200*	*400*
0.5	100.0	100.0	100.0	100.0	100.0	100.0
1	95.9	97.2	97.9	98.6	98.8	98.8
2	87.9	91.7	93.0	94.0	94.5	94.6
3	80.7	86.5	88.1	89.4	90.1	90.5
4	73.8	81.0	83.2	84.8	85.7	86.4
5	67.8	75.7	78.4	80.2	81.3	82.3
6	62.3	70.6	73.6	75.6	76.9	78.2
7	57.3	65.7	68.8	71.0	72.5	74.1
8	52.7	61.0	64.2	66.5	68.3	70.1
9	48.5	56.5	59.7	62.1	64.2	66.2
10	44.7	52.3	55.5	57.9	60.3	62.5
11	41.2	48.4	51.6	54.0	56.6	58.8
12	38.0	44.8	48.0	50.4	53.1	55.4
13	35.0	41.5	44.6	47.1	49.8	52.2
14	32.2	38.5	41.5	44.0	46.7	49.2
15	29.6	35.7	38.6	41.1	43.8	46.4
16	27.2	33.1	35.9	38.4	41.1	43.7
17	25.0	30.7	33.4	35.9	38.6	41.2
18	23.0	28.5	31.1	33.6	36.3	38.8
19	21.2	26.4	29.0	31.4	34.1	36.6
20	19.5	24.4	27.0	29.2	32.0	34.5

DEPTH DOSE IN WATER FOR LINEAR ACCELERATOR FOR 100% AT PEAK
4.2 MEV FSD 100 CM HVL 15.7 MM CU
Courtesy of M. J. Day and F. T. Farmer: *Brit. J Radiol.*

Field Size	*Zero Area*	*2×2*	*4×4*	*6×6*	*8×8*	*10×10*	*12×12*	*14×14*	*16×16*	*18×18*	*20×20*
Equiv dia	*0*	*cm* *2.2*	*cm* *4.5*	*cm* *6.7*	*cm* *9.0*	*cm* *11.2*	*cm* *13.4*	*cm* *15.6*	*cm* *17.8*	*cm* *20.0*	*cm* *22.1*
Depth cm											
1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.35	99.0	99.0	99.1	99.1	99.2	99.2	99.3	99.3	99.3	99.4	99.5
1.5	97.9	98.0	98.0	98.1	98.3	98.5	98.7	98.8	99.0	99.2	99.3
2	93.9	94.6	95.2	96.0	96.4	96.7	97.0	97.2	97.4	97.7	97.9
4	80.2	82.9	85.0	86.6	87.5	88.1	88.6	89.0	89.3	89.7	90.1
6	68.6	71.9	74.6	76.8	78.0	78.9	79.5	80.0	80.6	81.2	81.6
8	59.1	61.9	65.0	67.7	69.3	70.5	71.3	72.1	72.7	73.3	73.7
10	50.9	53.6	56.7	59.6	61.5	62.9	63.9	65.0	65.7	66.5	67.1
12	44.2	46.4	49.3	52.1	54.3	55.8	57.0	57.9	59.0	59.8	60.5
14	38.2	40.2	42.8	45.5	47.4	49.0	50.2	51.3	52.3	53.3	54.0
16	33.4	35.3	37.6	39.9	41.5	43.5	44.8	45.9	47.0	47.9	48.7
18	29.2	30.7	32.7	34.8	36.8	38.4	39.6	40.8	41.8	42.8	43.5
20	25.5	26.8	28.6	30.6	32.6	34.0	35.3	36.4	37.4	38.3	39.2
22	22.3	23.4	25.2	26.9	28.5	30.0	31.3	32.3	33.2	34.2	34.9
24	19.5	20.6	22.0	23.6	25.2	26.5	27.6	28.6	29.5	30.5	31.2
26	17.1	18.0	19.5	20.8	22.3	23.4	24.4	25.3	26.2	27.0	27.8
28	14.9	15.8	17.0	18.4	19.6	20.7	21.6	22.4	23.3	24.1	24.7
30	13.1	14.0	15.1	16.3	17.3	18.3	19.1	19.8	20.7	21.4	22.0

22 MEV BETATRON RADIATION WITH COPPER COMPENSATING FILTER

Depth	*FSD – 70 cm*	*FSD – 100 cm*
0.0	20	19
0.5	51.0	50.0
1.0	71.0	70.0
2.0	92.8	90.1
3.0	99.2	98.0
4.0	100.0	100.0
5.0	98.2	99.5
6.0	93.3	96.6
7.0	89.0	93.0
8.0	84.9	89.1
9.0	81.0	85.3
10.0	77.1	81.9
11.0	73.5	78.5
12.0	70.0	75.5
13.0	66.7	72.5
14.0	63.6	69.6
15.0	60.5	67.0
16.0	57.7	64.2
17.0	55.0	61.6
18.0	52.4	59.1
19.0	49.9	56.8
20.0	47.5	54.5

DEPTH DOSE--Continued

Rectangular Fields HVL 0.5 mm Cu FSD 50 cm
Rectangular Fields in cm × cm

Depth in cm	*4×4*	*4×6*	*4×8*	*4×10*	*4×15*	*4×20*	*6×6*	*6×8*	*6×10*	*6×15*	*6×20*
*	121.4	124.4	126.1	127.2	128.5	129.2	128.3	130.6	132.1	134.0	135.0
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	91.4	92.7	93.3	93.8	94.3	94.4	94.2	95.1	95.6	96.3	96.5
2	77.6	79.7	80.9	81.6	82.5	82.8	82.4	83.9	84.9	86.0	86.4
3	64.4	66.9	68.4	69.4	70.5	71.1	70.2	72.2	73.3	74.8	75.5
4	52.6	55.4	57.1	58.2	59.5	60.1	59.0	61.3	62.6	64.3	65.2
5	42.9	45.7	47.4	48.6	50.0	50.7	49.3	51.6	53.0	54.9	55.8
6	35.0	37.7	39.4	40.4	41.9	42.6	41.1	43.3	44.6	46.6	47.6
7	28.5	31.0	32.6	33.5	35.0	35.7	34.2	36.2	37.4	39.4	40.4
8	23.5	25.6	27.0	27.9	29.3	30.0	28.4	30.2	31.4	33.3	34.2
9	19.4	21.2	22.4	23.2	24.6	25.2	23.6	25.1	26.3	28.1	29.0
10	16.0	17.5	18.6	19.3	20.6	21.1	19.6	21.0	22.0	23.7	24.6
11	13.1	14.5	15.5	16.1	17.2	17.8	16.3	17.6	18.5	20.0	20.9
12	10.7	12.0	12.9	13.5	14.4	15.0	13.6	14.8	15.6	16.9	17.7
13	8.8	9.9	10.7	11.3	12.1	12.6	11.3	12.4	13.1	14.3	15.0
14	7.3	8.2	8.9	9.4	10.1	10.6	9.4	10.3	11.0	12.1	12.8
15	6.0	6.8	7.4	7.8	8.5	8.9	7.8	8.6	9.2	10.2	10.7
16	5.0	5.6	6.1	6.5	7.1	7.5	6.5	7.2	7.7	8.6	9.1
17	4.1	4.7	5.1	5.4	5.9	6.3	5.4	6.0	6.4	7.2	7.7
18	3.3	3.9	4.2	4.5	5.0	5.3	4.5	5.0	5.4	6.1	6.5
19	2.7	3.2	3.5	3.8	4.2	4.5	3.8	4.2	4.6	5.2	5.5
20	2.2	2.6	2.9	3.1	3.5	3.7	3.1	3.5	3.8	4.3	4.7

Depth in cm	*8×8*	*8×10*	*8×15*	*8×20*	*10×10*	*10×15*	*10×20*	*15×15*	*15×20*	*20×20*
*	133.4	135.2	137.6	139.0	137.3	140.1	141.8	143.9	146.2	148.9
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	96.1	96.7	97.6	97.8	97.5	98.4	98.6	99.4	99.6	99.8
2	85.8	86.7	88.1	88.6	87.9	89.5	90.1	91.3	92.0	92.9
3	74.3	75.7	77.6	78.5	77.3	79.4	80.4	81.9	83.2	84.7
4	63.8	65.3	67.4	68.5	67.1	69.5	70.7	72.4	73.9	75.7
5	54.2	55.8	58.1	59.2	57.7	60.3	61.6	63.5	65.1	66.9
6	45.8	47.4	49.8	51.0	49.2	52.0	53.4	55.4	57.0	58.9
7	38.6	40.1	42.5	43.7	41.8	44.6	46.0	48.0	49.7	51.6
8	32.3	33.8	36.1	37.3	35.4	38.1	39.5	41.4	43.1	45.0
9	27.0	28.4	30.6	31.8	30.0	32.5	33.8	35.6	37.3	39.2
10	22.7	24.0	26.0	27.1	25.4	27.7	29.0	30.6	32.3	34.1
11	19.1	20.3	22.0	23.1	21.5	23.6	24.8	26.3	27.8	29.6
12	16.1	17.1	18.7	19.7	18.3	20.1	21.2	22.5	24.0	25.7
13	13.6	14.5	15.9	16.8	15.5	17.2	18.2	19.3	20.7	22.2
14	11.4	12.2	13.5	14.3	13.1	14.7	15.6	16.6	17.8	19.2
15	9.5	10.2	11.4	12.2	11.0	12.5	13.3	14.2	15.3	16.6
16	8.0	8.5	9.6	10.4	9.3	10.6	11.4	12.2	13.2	14.4
17	6.7	7.2	8.2	8.8	7.9	9.0	9.7	10.5	11.4	12.4
18	5.6	6.1	7.0	7.5	6.7	7.7	8.3	9.0	9.8	10.7
19	4.7	5.2	6.0	6.4	5.7	6.6	7.1	7.7	8.5	9.3
20	4.0	4.3	5.0	5.4	4.8	5.6	6.1	6.6	7.3	8.0

*The first line gives the surface dose for 100 r of primary.

DEPTH DOSE--Continued

Rectangular Fields HVL 1.0 mm Cu FSD 50 cm
Rectangular Fields in cm × cm

Depth in cm	*4×4*	*4×6*	*4×8*	*4×10*	*4×15*	*4×20*	*6×6*	*6×8*	*6×10*	*6×15*	*6×20*
*	118.0	121.1	123.0	124.3	125.8	126.6	125.2	127.9	129.7	131.8	133.0
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	92.9	94.7	95.5	96.0	96.6	96.8	96.9	97.9	98.5	99.3	99.5
2	81.3	84.3	85.7	86.5	87.4	87.7	87.9	89.6	90.6	91.7	92.1
3	70.3	73.5	75.3	76.5	77.8	78.3	77.4	79.8	81.3	82.9	83.6
4	60.0	63.2	65.1	66.4	68.0	68.7	67.2	69.7	71.3	73.4	74.4
5	50.7	53.8	55.8	57.1	58.7	59.5	57.7	60.2	61.9	64.2	65.2
6	42.7	45.5	47.4	48.8	50.4	51.3	49.2	51.6	53.4	55.7	56.8
7	35.8	38.3	40.1	41.5	43.1	44.0	41.7	44.1	45.8	48.1	49.2
8	29.9	32.2	33.9	35.2	36.8	37.7	35.3	37.6	39.2	41.4	42.5
9	25.0	27.1	28.7	29.8	31.4	32.2	29.9	32.0	33.5	35.6	36.7
10	20.9	22.8	24.2	25.2	26.7	27.5	25.3	27.2	28.6	30.6	31.6
11	17.4	19.2	20.4	21.3	22.7	23.5	21.4	23.1	24.3	26.2	27.2
12	14.6	16.2	17.3	18.1	19.4	20.1	18.1	19.6	20.7	22.5	23.4
13	12.2	13.6	14.6	15.4	16.5	17.1	15.3	16.6	17.6	19.3	20.1
14	10.2	11.4	12.3	13.0	14.0	14.6	12.9	14.1	15.0	16.5	17.2
15	8.6	9.6	10.4	11.0	11.9	12.5	10.9	12.0	12.8	14.1	14.8
16	7.2	8.1	8.7	9.3	10.1	10.7	9.2	10.2	10.9	12.0	12.7
17	6.0	6.8	7.3	7.8	8.6	9.1	7.8	8.6	9.2	10.3	10.9
18	5.0	5.7	6.2	6.6	7.3	7.7	6.6	7.3	7.8	8.8	9.4
19	4.2	4.8	5.2	5.6	6.2	6.6	5.6	6.2	6.7	7.5	8.1
20	3.5	4.0	4.4	4.8	5.3	5.6	4.7	5.3	5.7	6.4	6.9

Depth in cm	*8×8*	*8×10*	*8×15*	*8×20*	*10×10*	*10×15*	*10×20*	*15×15*	*15×20*	*20×20*
*	131.1	133.3	136.0	137.5	135.7	138.9	140.7	143.0	145.6	148.7
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	99.1	99.8	100.7	100.9	100.6	101.5	101.8	102.6	102.8	103.0
2	91.6	92.8	94.0	94.5	94.0	95.4	95.9	97.0	97.6	98.4
3	82.5	84.2	86.2	87.0	86.1	88.3	89.2	90.9	92.0	93.4
4	72.6	74.5	77.0	78.1	76.6	79.4	80.7	82.8	84.4	86.1
5	63.2	65.2	67.8	69.1	67.3	70.3	71.8	74.0	75.8	77.8
6	54.6	56.6	59.4	60.6	58.8	61.9	63.4	65.6	67.5	69.7
7	46.9	48.9	51.7	52.9	51.1	54.2	55.7	57.9	59.9	62.2
8	40.2	42.1	44.8	46.1	44.2	47.2	48.8	50.9	53.0	55.3
9	34.4	36.2	38.7	40.1	38.2	41.1	42.6	44.6	46.7	49.1
10	29.4	31.1	33.4	34.8	32.9	35.6	37.1	39.0	41.0	43.4
11	25.1	26.6	28.8	30.2	28.3	30.8	32.3	34.0	35.9	38.2
12	21.4	22.7	24.9	26.1	24.3	26.6	28.1	29.6	31.4	33.5
13	18.3	19.4	21.4	22.5	20.8	23.0	24.3	25.8	27.4	29.3
14	15.6	16.6	18.4	19.4	17.8	19.8	21.0	22.4	23.9	25.7
15	13.2	14.2	15.8	16.7	15.3	17.1	18.2	19.4	20.8	22.5
16	11.2	12.1	13.5	14.4	13.1	14.8	15.8	16.9	18.2	19.7
17	9.5	10.3	11.6	12.4	11.2	12.7	13.7	14.7	15.9	17.2
18	8.1	8.8	10.0	10.7	9.6	10.9	11.8	12.7	13.8	15.1
19	7.0	7.6	8.6	9.3	8.3	9.4	10.2	11.0	12.0	13.2
20	6.0	6.5	7.4	8.0	7.1	8.1	8.8	9.5	10.4	11.5

* The first line gives the surface dose for 100 r of primary.

DEPTH DOSE--Continued

RECTANGULAR FIELDS HVL 3.0 MM CU FSD 50 CM
RECTANGULAR FIELDS IN CM × CM

Depth in cm	*4×4*	*4×6*	*4×8*	*4×10*	*4×15*	*4×20*	*6×6*	*6×8*	*6×10*	*6×15*	*6×20*
*	111.6	113.7	114.9	115.8	117.0	117.6	116.4	118.2	119.4	121.1	122.1
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	93.9	95.1	95.6	95.9	96.3	96.5	96.5	97.1	97.5	98.1	98.3
2	84.6	86.2	87.1	87.6	88.4	88.7	88.3	89.4	90.1	91.2	91.5
3	73.7	76.0	77.3	78.1	79.2	79.7	78.8	80.5	81.6	83.1	83.6
4	63.1	65.8	67.4	68.4	69.6	70.3	69.0	71.0	72.4	74.1	75.0
5	54.2	56.7	58.4	59.5	60.9	61.6	60.1	62.2	63.7	65.6	66.6
6	46.3	48.7	50.4	51.5	53.1	53.8	52.0	54.2	55.7	57.8	58.8
7	39.3	41.7	43.4	44.5	46.1	46.8	44.9	47.1	48.6	50.8	51.8
8	33.4	35.7	37.3	38.5	40.0	40.7	38.7	40.9	42.4	44.5	45.6
9	28.5	30.6	32.1	33.2	34.7	35.4	33.4	35.4	36.9	38.9	40.0
10	24.3	26.2	27.6	28.6	30.0	30.8	28.7	30.6	32.0	34.0	35.0
11	20.7	22.4	23.7	24.6	26.0	26.7	24.7	26.4	27.7	29.6	30.6
12	17.6	19.1	20.4	21.2	22.5	23.1	21.2	22.8	24.0	25.7	26.7
13	15.1	16.3	17.5	18.3	19.5	20.0	18.2	19.7	20.8	22.4	23.3
14	12.9	14.0	15.0	15.7	16.9	17.4	15.7	17.0	18.0	19.5	20.3
15	11.0	12.0	12.8	13.5	14.6	15.1	13.5	14.6	15.5	17.0	17.7
16	9.4	10.3	11.0	11.6	12.6	13.1	11.6	12.6	13.4	14.8	15.5
17	8.0	8.8	9.4	10.0	10.9	11.4	10.0	10.9	11.6	12.9	13.5
18	6.8	7.5	8.1	8.6	9.4	9.9	8.6	9.4	10.0	11.2	11.8
19	5.8	6.4	7.0	7.4	8.1	8.6	7.4	8.1	8.7	9.8	10.3
20	4.9	5.5	6.0	6.4	7.1	7.5	6.3	7.0	7.6	8.5	9.0

Depth in cm	*8×8*	*8×10*	*8×15*	*8×20*	*10×10*	*10×15*	*10×20*	*15×15*	*15×20*	*20×20*
*	120.4	121.9	124.1	125.3	123.7	126.2	127.7	129.6	131.5	133.7
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	97.9	98.3	99.1	99.3	98.9	99.7	100.0	100.6	101.0	101.4
2	90.7	91.6	92.8	93.3	92.6	93.9	94.5	95.6	96.2	96.8
3	82.4	83.7	85.4	86.3	85.1	87.0	88.1	89.5	90.8	92.3
4	73.4	74.9	77.1	78.1	76.7	79.1	80.3	82.1	83.8	85.7
5	64.8	66.5	68.8	70.0	68.4	71.1	72.5	74.5	76.2	78.3
6	56.8	58.6	61.1	62.3	60.6	63.5	65.0	67.0	68.9	71.3
7	49.7	51.5	54.1	55.3	53.6	56.5	58.1	60.1	62.0	64.2
8	43.4	45.2	47.7	49.0	47.2	50.1	51.7	53.7	55.6	57.9
9	37.8	39.6	42.0	43.3	41.5	44.3	45.9	47.9	49.8	52.0
10	32.8	34.5	36.9	38.1	36.3	39.1	40.6	42.6	44.5	46.7
11	28.5	30.0	32.3	33.5	31.7	34.4	35.8	37.7	39.6	41.7
12	24.8	26.1	28.3	29.4	27.7	30.3	31.5	33.3	35.1	37.2
13	21.5	22.7	24.7	25.8	24.2	26.6	27.8	29.4	31.1	33.1
14	18.6	19.7	21.6	22.6	21.1	23.3	24.5	25.9	27.5	29.4
15	16.1	17.1	18.9	19.8	18.4	20.4	21.6	22.9	24.4	26.2
16	13.9	14.9	16.5	17.4	16.0	17.9	19.0	20.2	21.6	23.2
17	12.0	13.0	14.4	15.3	13.9	15.7	16.7	17.8	19.1	20.7
18	10.4	11.3	12.6	13.4	12.2	13.8	14.7	15.7	16.9	18.5
19	9.0	9.8	11.1	11.8	10.7	12.1	13.0	13.9	15.0	16.4
20	7.8	8.5	9.7	10.3	9.3	10.6	11.4	12.3	13.3	14.5

*The first line gives the surface dose for 100 r of primary.

DEPTH DOSE--Continued

Rectangular Fields Cobalt 60 FSD 50 cm
Rectangular Fields in cm × cm

Depth in cm	*4×4*	*4×6*	*4×8*	*4×10*	*4×15*	*4×20*	*6×6*	*6×8*	*6×10*	*6×15*	*6×20*
*	101.1	101.3	101.5	101.6	101.8	101.9	101.6	101.8	102.0	102.3	102.5
0	Surface dose 30 to 50% depending upon collimator										
0.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	96.0	96.3	96.5	96.6	96.6	96.6	96.7	96.9	97.0	97.1	97.1
2	88.7	89.3	89.6	89.8	89.9	89.9	90.1	90.5	90.6	90.8	90.9
3	81.6	82.5	82.9	83.1	83.3	83.4	83.6	84.1	84.4	84.7	84.8
4	75.0	76.0	76.5	76.7	77.0	77.1	77.3	77.9	78.3	78.7	78.9
5	68.8	70.0	70.4	70.7	71.1	71.2	71.3	72.0	72.5	73.0	73.2
6	63.0	64.1	64.7	65.1	65.5	65.6	65.6	66.4	66.9	67.5	67.8
7	57.6	58.7	59.4	59.8	60.2	60.4	60.2	61.1	61.6	62.2	62.6
8	52.6	53.7	54.4	54.8	55.3	55.5	55.2	56.1	56.6	57.3	57.7
9	48.0	49.1	49.8	50.1	50.7	51.0	50.5	51.4	52.0	52.7	53.2
10	43.8	44.9	45.5	45.9	46.5	46.8	46.2	47.1	47.7	48.5	49.0
11	40.0	41.0	41.6	42.0	42.6	43.0	42.3	43.2	43.8	44.7	45.1
12	36.5	37.5	38.1	38.5	39.1	39.5	38.8	39.7	40.2	41.1	41.6
13	33.3	34.3	34.9	35.3	35.9	36.3	35.6	36.4	37.0	37.9	38.4
14	30.5	31.4	32.0	32.4	33.0	33.4	32.6	33.4	34.0	34.9	35.4
15	27.9	28.7	29.3	29.7	30.3	30.7	29.9	30.6	31.2	32.1	32.7
16	25.5	26.2	26.8	27.2	27.9	28.2	27.4	28.1	28.7	29.6	30.2
17	23.3	24.0	24.6	24.9	25.6	26.0	25.1	25.8	26.4	27.3	27.9
18	21.3	22.0	22.6	22.9	23.5	24.0	23.0	23.7	24.3	25.2	25.8
19	19.5	20.2	20.7	21.0	21.6	22.1	21.1	21.8	22.4	23.3	23.8
20	17.8	18.5	19.0	19.3	19.9	20.3	19.4	20.0	20.6	21.5	22.0

Depth in cm	*8×8*	*8×10*	*8×15*	*8×20*	*10×10*	*10×15*	*10×20*	*15×15*	*15×20*	*20×20*
*	102.1	102.3	102.7	103.0	102.5	103.0	103.4	103.7	104.1	104.6
0	Surface dose 30 to 50% depending upon collimator									
0.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	97.1	97.3	97.4	97.4	97.5	97.6	97.6	97.7	97.7	97.7
2	90.9	91.1	91.3	91.4	91.4	91.6	91.7	91.9	92.0	92.1
3	84.7	85.0	85.4	85.5	85.4	85.8	86.0	86.2	86.5	86.7
4	78.7	79.1	79.6	79.8	79.6	80.1	80.4	80.7	81.1	81.5
5	72.9	73.4	74.0	74.3	74.0	74.6	75.0	75.4	75.9	76.4
6	67.4	67.9	68.6	69.0	68.6	69.4	69.8	70.3	70.9	71.6
7	62.1	62.7	63.5	64.0	63.4	64.4	64.9	65.5	66.2	67.0
8	57.1	57.7	58.6	59.2	58.5	59.6	60.2	60.9	61.7	62.6
9	52.4	53.1	54.1	54.7	53.9	55.1	55.8	56.6	57.5	58.5
10	48.1	48.8	49.9	50.5	49.7	50.9	51.7	52.5	53.6	54.7
11	44.2	44.9	46.0	46.7	45.8	47.1	47.9	48.7	49.9	51.1
12	40.7	41.4	42.5	43.2	42.2	43.6	44.4	45.2	46.4	47.7
13	37.4	38.1	39.2	39.9	39.0	40.3	41.1	42.0	43.2	44.5
14	34.4	35.1	36.2	36.9	36.0	37.3	38.1	39.0	40.2	41.6
15	31.6	32.3	33.4	34.1	33.2	34.5	35.3	36.3	37.5	38.8
16	29.1	29.7	30.9	31.6	30.6	32.0	32.8	33.8	35.0	36.3
17	26.8	27.4	28.6	29.3	28.2	29.7	30.5	31.5	32.7	34.0
18	24.7	25.3	26.5	27.2	26.1	27.5	28.3	29.3	30.5	31.8
19	22.7	23.4	24.5	25.2	24.1	25.5	26.3	27.3	28.5	29.8
20	20.9	21.6	22.7	23.3	22.2	23.7	24.4	25.4	26.6	27.9

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*The first line gives the dose at the maximum for 100 r of primary.

DEPTH DOSE--Continued

Rectangular Fields Cobalt 60 FSD 60 cm
Rectangular Fields in cm × cm

Depth in cm	*4×4*	*4×6*	*4×8*	*4×10*	*4×15*	*4×20*	*6×6*	*6×8*	*6×10*	*6×15*	*6×20*
*	101.0	101.3	101.4	101.5	101.7	101.9	101.6	101.8	102.0	102.3	102.5
0	Surface dose 30 to 50% depending upon collimator										
0.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	96.5	96.7	96.8	96.9	97.0	97.0	97.0	97.2	97.3	97.4	97.4
2	89.7	90.2	90.5	90.7	90.8	90.8	90.8	91.2	91.4	91.6	91.7
3	83.2	83.9	84.3	84.6	84.8	84.8	84.8	85.3	85.6	85.9	86.1
4	77.0	77.8	78.3	78.6	78.9	79.0	78.9	79.6	80.0	80.3	80.5
5	71.0	71.9	72.5	72.8	73.1	73.4	73.2	74.0	74.5	74.8	75.1
6	65.4	66.4	67.0	67.3	67.7	68.0	67.7	68.6	69.1	69.6	69.9
7	60.1	61.2	61.8	62.1	62.6	62.8	62.5	63.4	63.9	64.5	64.9
8	55.1	56.2	56.8	57.2	57.7	57.9	57.6	58.4	59.0	59.7	60.1
9	50.4	51.5	52.1	52.6	53.1	53.4	53.0	53.8	54.4	55.1	55.6
10	46.1	47.2	47.8	48.3	48.8	49.2	48.7	49.5	50.1	50.9	51.4
11	42.2	43.3	43.9	44.4	44.9	45.3	44.8	45.6	46.2	47.0	47.5
12	38.7	39.8	40.4	40.9	41.4	41.8	41.2	42.0	42.6	43.4	44.0
13	35.5	36.5	37.2	37.6	38.2	38.5	37.9	38.7	39.3	40.1	40.7
14	32.5	33.5	34.2	34.6	35.2	35.5	34.8	35.7	36.3	37.1	37.7
15	29.8	30.8	31.4	31.8	32.4	32.8	32.0	32.9	33.5	34.3	34.9
16	27.4	28.3	28.9	29.3	29.9	30.3	29.4	30.3	30.9	31.7	32.3
17	25.2	26.1	26.6	27.0	27.6	28.0	27.1	28.0	28.5	29.3	29.9
18	23.2	24.0	24.5	24.9	25.5	25.9	25.0	25.8	26.3	27.2	27.8
19	21.3	22.1	22.6	22.9	23.6	23.9	23.0	23.8	24.3	25.2	25.8
20	19.5	20.3	20.8	21.0	21.8	22.0	21.1	21.9	22.4	23.3	23.9

Depth in cm	*8×8*	*8×10*	*8×15*	*8×20*	*10×10*	*10×15*	*10×20*	*15×15*	*15×20*	*20×20*
*	102.1	102.3	102.7	102.9	102.5	103.0	103.3	103.6	104.1	104.6
0	Surface dose 30 to 50% depending upon collimator									
0.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	97.4	97.5	97.7	97.7	97.7	97.8	97.9	98.0	98.0	98.1
2	91.7	91.9	92.1	92.2	92.1	92.4	92.5	92.7	92.8	93.0
3	86.0	86.3	86.6	86.8	86.6	87.1	87.2	87.5	87.7	88.0
4	80.3	80.7	81.2	81.4	81.2	81.8	82.0	82.4	82.7	83.1
5	74.8	75.3	75.9	76.2	75.9	76.6	76.9	77.4	77.8	78.3
6	69.5	70.0	70.7	71.1	70.7	71.5	71.9	72.5	73.0	73.7
7	64.4	64.9	65.7	66.2	65.6	66.6	67.0	67.8	68.4	69.2
8	59.5	60.1	61.0	61.5	60.8	61.9	62.4	63.3	64.0	64.9
9	54.9	55.6	56.6	57.1	56.3	57.5	58.1	59.0	59.8	60.9
10	50.6	51.3	52.4	52.9	52.1	53.4	54.0	54.9	55.8	57.0
11	46.7	47.4	48.5	49.1	48.2	49.5	50.2	51.1	52.1	53.4
12	43.1	43.8	44.9	45.6	44.6	45.9	46.7	47.6	48.7	50.0
13	39.8	40.5	41.6	42.3	41.3	42.6	43.4	44.4	45.5	46.9
14	36.7	37.5	38.5	39.2	38.2	39.6	40.4	41.4	42.5	43.9
15	33.9	34.6	35.7	36.4	35.4	36.8	37.6	38.6	39.7	41.1
16	31.3	32.0	33.1	33.8	32.8	34.2	35.0	36.0	37.1	38.5
17	28.9	29.6	30.7	31.4	30.4	31.8	32.6	33.6	34.8	36.1
18	26.7	27.4	28.5	29.2	28.2	29.6	30.4	31.4	32.6	33.9
19	24.7	25.4	26.5	27.2	26.2	27.5	28.4	29.3	30.5	31.8
20	22.8	23.4	24.6	25.3	24.2	25.5	26.4	27.3	28.5	29.8

*The first line gives the dose at the maximum for 100 r of primary.

DEPTH DOSE--Continued

Rectangular Fields Cobalt 60 FSD 80 cm
Rectangular Fields in cm × cm

Depth in cm	*4×4*	*4×6*	*4×8*	*4×10*	*4×15*	*4×20*	*6×6*	*6×8*	*6×10*	*6×15*	*6×20*
*	101.1	101.3	101.5	101.6	101.8	101.9	101.6	101.8	102.0	102.3	102.5
0	Surface dose 30 to 50% depending upon collimator										
0.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	96.8	97.0	97.2	97.3	97.4	97.4	97.4	97.6	97.7	97.8	97.8
2	90.6	91.2	91.5	91.6	91.8	91.8	91.9	92.2	92.5	92.7	92.8
3	84.7	85.5	85.9	86.1	86.4	86.4	86.5	86.9	87.3	87.6	87.7
4	79.0	79.9	80.4	80.6	81.0	81.1	81.1	81.7	82.1	82.5	82.7
5	73.5	74.5	75.1	75.3	75.7	75.9	75.9	76.6	77.0	77.5	77.7
6	68.1	69.2	69.9	70.1	70.5	70.7	70.7	71.5	71.9	72.5	72.7
7	62.9	64.1	64.8	65.1	65.5	65.7	65.7	66.5	67.0	67.6	67.9
8	58.0	59.2	59.9	60.3	60.8	61.0	60.8	61.7	62.2	62.9	63.3
9	53.5	54.7	55.3	55.8	56.3	56.6	56.2	57.1	57.7	58.5	58.9
10	49.3	50.5	51.1	51.6	52.2	52.5	52.0	52.9	53.5	54.4	54.8
11	45.5	46.6	47.3	47.8	48.4	48.6	48.1	49.0	49.6	50.5	51.0
12	41.9	43.0	43.7	44.2	44.8	45.1	44.5	45.4	46.0	46.9	47.4
13	38.6	39.7	40.4	40.9	41.4	41.8	41.1	42.0	42.7	43.6	44.1
14	35.6	36.6	37.3	37.8	38.4	38.7	38.0	38.9	39.6	40.5	41.0
15	32.9	33.8	34.5	35.0	35.6	35.9	35.2	36.1	36.7	37.6	38.1
16	30.4	31.3	32.0	32.4	33.1	33.4	32.6	33.5	34.1	35.0	35.5
17	28.1	29.0	29.6	30.0	30.7	31.0	30.2	31.1	31.6	32.6	33.1
18	26.0	26.9	27.4	27.9	28.5	28.8	28.0	28.8	29.4	30.3	30.8
19	24.0	24.9	25.4	25.9	26.5	26.8	26.0	26.7	27.4	28.2	28.7
20	22.1	22.9	23.5	23.9	24.5	24.8	24.0	24.8	25.4	26.2	26.8

Depth in cm	*8×8*	*8×10*	*8×15*	*8×20*	*10×10*	*10×15*	*10×20*	*15×15*	*15×20*	*20×20*
*	102.1	102.3	102.7	102.9	102.5	103.0	103.3	103.6	104.1	104.6
0	Surface dose 30 to 50% depending upon collimator									
0.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	97.8	98.0	98.1	98.1	98.2	98.3	98.3	98.4	98.4	98.4
2	92.7	93.0	93.2	93.3	93.3	93.6	93.6	93.9	93.9	94.0
3	87.6	87.9	88.3	88.5	88.3	88.8	88.9	89.3	89.4	89.6
4	82.5	82.9	83.4	83.6	83.4	84.0	84.2	84.7	84.9	85.2
5	77.4	77.9	78.5	78.8	78.5	79.2	79.5	80.1	80.4	80.8
6	72.4	73.0	73.7	74.0	73.6	74.4	74.7	75.4	75.8	76.4
7	67.5	68.1	68.9	69.2	68.8	69.8	70.1	70.8	71.4	72.1
8	62.7	63.4	64.3	64.7	64.1	65.2	65.7	66.5	67.2	68.0
9	58.2	58.9	59.9	60.4	59.7	60.9	61.4	62.3	63.1	64.0
10	54.0	54.8	55.8	56.3	55.6	56.9	57.4	58.4	59.2	60.2
11	50.1	50.9	52.0	52.5	51.7	53.1	53.7	54.7	55.6	56.6
12	46.5	47.3	48.4	49.0	48.1	49.5	50.2	51.2	52.1	53.2
13	43.2	44.0	45.1	45.7	44.8	46.2	46.9	47.9	48.8	50.0
14	40.1	40.9	42.0	42.6	41.8	43.1	43.9	44.9	45.8	47.0
15	37.2	38.0	39.2	39.8	38.9	40.3	41.0	42.0	43.0	44.2
16	34.5	35.3	36.5	37.1	36.2	37.6	38.3	39.3	40.3	41.5
17	32.1	32.8	34.0	34.6	33.7	35.1	35.8	36.8	37.8	39.0
18	29.8	30.5	31.7	32.3	31.4	32.8	33.5	34.5	35.5	36.7
19	27.7	28.4	29.6	30.2	29.2	30.7	31.4	32.3	33.4	34.6
20	25.7	26.4	27.6	28.2	27.2	28.6	29.4	30.3	31.4	32.6

* The first line gives the dose at the maximum for 100 r of primary.

DEPTH DOSE--Continued

Rectangular Fields Cobalt 60 FSD 100 cm
Rectangular Fields in cm × cm

Depth in cm	4×4	4×6	4×8	4×10	4×15	4×20	6×6	6×8	6×10	6×15	6×20
*	101.1	101.3	101.5	101.6	101.8	101.9	101.6	101.8	102.0	102.3	102.5
0	Surface dose 30 to 50% depending upon collimator										
0.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	97.1	97.3	97.5	97.6	97.7	97.7	97.7	97.9	98.0	98.2	98.2
2	91.4	91.9	92.2	92.4	92.5	92.6	92.6	92.9	93.1	93.4	93.4
3	85.8	86.5	86.9	87.2	87.3	87.5	87.5	87.9	88.2	88.6	88.6
4	80.2	81.2	81.7	82.0	82.2	82.4	82.4	83.0	83.4	83.8	83.9
5	74.8	76.0	76.6	76.9	77.2	77.4	77.3	78.1	78.6	79.0	79.2
6	69.7	70.9	71.6	71.9	72.3	72.5	72.4	73.2	73.8	74.3	74.5
7	64.8	66.0	66.7	67.1	67.5	67.7	67.6	68.4	69.0	69.6	69.9
8	60.1	61.3	62.0	62.4	62.9	63.1	62.9	63.8	64.4	65.1	65.4
9	55.7	56.9	57.6	58.0	58.5	58.8	58.4	59.4	60.0	60.7	61.1
10	51.5	52.7	53.4	53.8	54.4	54.7	54.2	55.2	55.8	56.6	57.0
11	47.7	48.8	49.5	49.9	50.5	50.8	50.3	51.3	51.9	52.7	53.2
12	44.1	45.2	45.9	46.3	46.9	47.2	46.7	47.7	48.2	49.1	49.6
13	40.8	41.9	42.6	43.0	43.6	43.9	43.3	44.3	44.9	45.8	46.3
14	37.8	38.9	39.5	40.0	40.6	40.9	40.2	41.2	41.8	42.7	43.2
15	35.0	36.1	36.7	37.2	37.8	38.1	37.4	38.3	38.9	39.9	40.3
16	32.5	33.5	34.1	34.5	35.2	35.5	34.8	35.6	36.3	37.2	37.7
17	30.1	31.1	31.7	32.1	32.8	33.1	32.3	33.1	33.8	34.7	35.2
18	27.9	28.8	29.4	29.8	30.5	30.8	30.0	30.8	31.5	32.4	32.9
19	25.8	26.7	27.3	27.7	28.4	28.7	27.9	28.7	29.3	30.2	30.7
20	23.8	24.7	25.3	25.7	26.4	26.7	25.9	26.7	27.3	28.2	28.7

Depth in cm	8×8	8×10	8×15	8×20	10×10	10×15	10×20	15×15	15×20	20×20
*	102.1	102.3	102.7	103.0	102.5	103.0	103.4	103.7	104.1	104.6
0	Surface dose 30 to 50% depending upon collimator									
0.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1	98.1	98.3	98.5	98.5	98.6	98.8	98.8	99.0	98.9	98.9
2	93.3	93.6	93.9	93.9	93.9	94.3	94.3	94.6	94.6	94.7
3	88.5	88.9	89.3	89.3	89.3	89.8	89.8	90.2	90.3	90.5
4	83.7	84.2	84.7	84.8	84.7	85.3	85.4	85.9	86.1	86.3
5	78.9	79.6	80.1	80.3	80.1	80.8	81.0	81.6	81.9	82.2
6	74.2	74.9	75.6	75.8	75.5	76.3	76.6	77.3	77.7	78.1
7	69.5	70.2	71.0	71.3	70.9	71.8	72.2	73.0	73.5	74.0
8	64.9	65.6	66.5	66.9	66.4	67.4	67.9	68.7	69.3	70.0
9	60.5	61.2	62.1	62.6	62.0	63.1	63.7	64.5	65.2	66.1
10	56.3	57.0	58.0	58.6	57.8	59.0	59.7	60.6	61.3	62.3
11	52.4	53.1	54.2	54.8	53.9	55.2	55.9	56.9	57.7	58.7
12	48.7	49.5	50.7	51.2	50.3	51.7	52.4	53.4	54.3	55.3
13	45.4	46.1	47.3	47.9	47.0	48.4	49.1	50.2	51.1	52.1
14	42.3	43.0	44.2	44.8	43.9	45.3	46.0	47.1	48.1	49.1
15	39.4	40.1	41.3	41.9	41.0	42.4	43.1	44.2	45.2	46.2
16	36.7	37.4	38.6	39.2	38.3	39.7	40.4	41.5	42.5	43.5
17	34.2	34.9	36.1	36.7	35.8	37.2	37.9	39.0	40.0	41.0
18	31.9	32.6	33.8	34.4	33.5	34.9	35.6	36.7	37.6	38.6
19	29.7	30.5	31.6	32.3	31.3	32.7	33.4	34.5	35.4	36.4
20	27.7	28.5	29.6	30.2	29.3	30.6	31.3	32.4	33.3	34.4

* The first line gives the dose at the maximum for 100 r of primary.

Characteristics of some important (α, n) sources

Sources	Half-life	Maximum neutron energy	Average neutron energy	Yield	Remarks
		Mev	*Mev*	$\frac{n/sec \times 10^{-6}}{curie}$	
Po^{210}-Li	138.40d	1.32	0.48	.05	
Po^{210}-Be	138.40d	10.87	4.2	2.5	
RaDEF-Be	19.4y	10.87	4.5	2.5	Po-Be with a long half-life.
Ra-Be	1622y	13.08	[a] 3.9	15	
Em^{222}-Be	3.825d	13.08		15	
Pu^{239}-Be	24,400y	[a]10.74	4.5	0.064 (per g)	
Ac^{227}-Be	21.8y	12.79	4.6		Made by irradiating radium in reactor.
Po^{208}-Be	2.93y	10.71			
$RaBeF_4$	1622y	13.08		2.53	Proposed std source.
Po^{210}-B	138.40d	B^{10} 6.20, B^{11} 4.48.		0.6	Relatively monoenergetic.
Ra-B	1622y	B^{10} 8.58, B^{11} 7.25.		7	
Po^{210}-F	138.40d	2.8	1.4	0.2	
Po^{210}-Na	138.40d	4.45		0.04	
Am^{241}-Be	462y				Suggested for stoichiometric std source.
Cm^{242}-Be	162.5d				
Mock fission [b]	138.40d	10.87	1.6	0.4	

Characteristics of some important (γ,n) sources

Sources	Half-life	E_γ	E_n	Standard yield [a]	Actual source yield [b]
		Mev	*Mev*		
Na^{24}+Be	14.8h	2.76	0.83	13	
Na^{24}+D_2O	14.8h	2.76	0.22	27	
Ga^{72}+Be	14.1h	1.87, 2.21, 2.51	(0.78)	5	
Y^{88}+Be	87d	1.9, 2.8	0.158±0.005	10	
In^{116}+Be	54m	1.8, 2.1	0.30	0.82	
Sb^{124}+Be	60d	1.7	0.024±0.003	19	1.6
La^{140}+Be	40d	2.50	0.62	0.3	
RdTh+D_2O	1.90y	2.62 (ThC″)	0.197±0.010	9.5	[c] 1.2
MsTh+Be	6.7y	1.80, 2.62	0.827±0.030	3.5	
MsTH+D_2O	6.7y	2.62 (ThC″)	0.197±0.010	9.5	[c] 1.2
Ra+Be	1622y	1.69, 1.75, 1.82, 2.09, 2.20, 2.42.	0.7 max		1.3

[a] This is the neutron yield x 10^{-4} for a 1-curie gamma source with 1 g of target material placed 1 cm away from the gamma source.

[b] 10^6 n/sec-curie.

[c] Ms-Th and Rd-Th sources emit some neutrons through (α,n) reactions with light elements in the carrier and container walls.

NOTE: All photoneutron sources possess intense gamma-ray backgrounds of at least 10^3 gamma rays per neutron.

Characteristics of some important spontaneous fission neutron sources

Nuclide	Half-life (SF)	Half-life (α decay)	Alphas per fission [a]	Neutrons per fission	Neutrons per g sec
U^{232}	8×10^{13}y	74y	1.1×10^{13} 6.5×10^{12}, after aging. with 1.9 yr half-life		
Pu^{236}	3.5×10^{9}y	2.7y	1.3×10^{9}	1.9	3.1×10^{4}
U^{238}	8.3×10^{15}y	4.51×10^{9}y	1.8×10^{6}		
Pu^{238}	4.9×10^{10}y	89.6y	5.5×10^{8}	2.0	2.3×10^{3}
Pu^{240}	1.3×10^{11}y	6600y	1.9×10^{7}	2.1	7.0×10^{2}
Pu^{242}	7.2×10^{10}y	3.8×10^{5}y	1.9×10^{5}	2.3	
Cm^{242}	7.2×10^{6}y	162.5d	1.6×10^{7}	2.3	1.8×10^{7}
Cm^{244}	1.4×10^{7}y	18.4y	7.6×10^{5}	2.6	1.0×10^{7}
Cf^{252}	66y	2.2y	30		2.6×10^{12}
Cf^{254}	60d	60d	~0	3.5	

[a] The number of alphas/fission is an inverse "figure of merit." A source with a low number of alphas per fission has relatively many fissions and the neutron spectrum is not likely to be contaminated with (α,n) neutrons.

Data for tables from NBS Handbook No. 72.

PERSONNEL DECONTAMINATION

Method*	Surface	Action	Technique	Advantages	Disadvantages
Soap and water	Skin and hands	Emulsifies and dissolves contaminate.	Wash 2-3 minutes and monitor. Do not wash more than 3-4 times.	Readily available and effective for most radioactive contamination.	Continued washing will defat the skin. Indiscriminate washing of other than affected parts may spread contamination.
Soap and water	Hair	Same as above.	Wash several times. If contamination is not lowered to acceptable levels, shave the head and apply skin decontamination methods.		
Lava soap, soft brush, and water	Skin and hands	Emulsifies, dissolves, and erodes.	Use light pressure with heavy lather. Wash for 2 minutes, 3 times. Rinse and monitor. Use care not to scratch or erode the skin. Apply lanolin or hand cream to prevent chapping.	Same as above.	Continued washing will abrade the skin.
Tide or other detergent (plain)	Same as above.	Same as above.	Make into a paste. Use with additional water with a mild scrubbing action. Use care not to erode the skin.	Slightly more effective than washing with soap.	Will defat and abrade skin and must be used with care.

*Begin with the first listed method and then proceed step by step to the more severe methods, as necessary.

PERSONNEL DECONTAMINATION--Continued

Method*	Surface	Action	Technique	Advantages	Disadvantages
Mixture of 50% Tide and 50% cornmeal	Skin and hands	Emulsifies, dissolves, and erodes.	Make into a paste. Use with additional water with a mild scrubbing action. Use care not to erode the skin.	Slightly more effective than washing with soap.	Will defat and abrade skin and must be used with care.
5% water solution of a mixture of 30% Tide, 65% Calgon, 5% Carbose (carboxymethyl cellulose)	Same as above.	Same as above.	Use with water. Rub for a minute and rinse.	Same as above.	Same as above.
A preparation of 8% Carbose, 3% Tide, 1% Versene, and 88% water homogenized into a cream.	Same as above.	Same as above.	Use with additional water. Rub for 1 minute and wipe off. Follow with lanolin or hand cream.	Same as above.	Same as above.
Titanium dioxide paste. Prepare paste by mixing precipitated titanium dioxide (a very thick slurry, never permitted to dry) with a small amount of lanolin. If not successful, go on to next step.	Skin, hands, and extremities. Do not use near face or other body openings.	Same as above.	Work the paste into the affected area for 2 minutes. Rinse and wash with soap and warm water. Monitor.	Removes contamination lodged under scaly surface of skin. Good for heavy surface contamination of skin.	If left on too long will remove skin.

*Begin with the first listed method and then proceed step by step to the more severe methods, as necessary.

PERSONNEL DECONTAMINATION--Continued

Method*	Surface	Action	Technique	Advantages	Disadvantages
Mix equal volumes of a saturated solution of potassium permanganate and 0.2 N sulfuric acid. (Saturated solution of $KMnO_4$ is 6.4 grams per 100 ml of H_2O.) Continue with next step.	Skin, hands, and extremities. Do not use near face or other body openings.	Dissolves contaminant absorbed in the epidermis.	Pour over wet hands, rubbing the surface and using hand brush for not more than 2 minutes. Rinse with water.	Superior for skin contamination. May be used in conjunction with titanium oxide.	Will remove a layer of skin if in contact with the skin for more than 2 minutes.
Apply a freshly prepared 5% solution of sodium acid sulfite. (Solution made by dissolving 5 gm of $NaHSO_3$ crystals in 100 ml distilled water.)	Same as above.	Removes the permanganate stain.	Apply in same manner as above. Apply for not more than 2 minutes. The above procedure may be repeated. Apply lanolin or hand cream when completed.		Same as above.
Flushing	Eyes, ears, nose, and mouth	Physical removal by flushing.	Roll back the eyelid as far as possible, flush with large amounts of water. If isotonic irrigants are available, obtain them without delay. Apply to eye continually and then flush with large amounts of water.	If used immediately will remove contamination. May also be used for ears, nose, and throat.	When using for nose and mouth, contaminated individual should be warned not to swallow the rinses.

*Begin with the first listed method and then proceed step by step to the more severe methods, as necessary.

PERSONNEL DECONTAMINATION--Continued

Method*	Surface	Action	Technique	Advantages	Disadvantages
Flushing (Cont'd)			(Isotonic irrigant [0.9% NaCl solution]: 9 grams NaCl in beaker, fill to 1000 cc with water.) Can be purchased from drug suppliers, etc. Further decontamination should be done under medical supervision.		
Flushing	Wounds	Physical removal by flushing.	Wash would with large amounts of water and spread edges to stimulate bleeding, if not profuse. If profuse, stop bleeding first, clean edges of wound, bandage, and if any contamination remains, it may be removed by normal cleaning methods, as above.	Quick and efficient if wound not severe.	May spread contamination to other areas of body if not done carefully.
Sweating	Skin of hands and feet	Physical removal by sweating.	Place hand or foot in plastic glove or booty. Tape shut. Place near source of heat for 10-15 minutes or	Cleansing action is from inside out. Hand does not dry out.	If glove or booty is not removed shortly after profuse sweating starts and part washed with soap

*Begin with the first listed method and then proceed step by step to the more severe methods, as necessary.

PERSONNEL DECONTAMINATION--Continued

Method*	Surface	Action	Technique	Advantages	Disadvantages
Sweating (Cont'd)			until hand or foot is sweating profusely. Remove glove and then wash using standard techniques. Or gloves can be worn for several hours using only body heat.		and water immediately, contamination may seep into the pores.

AREA AND MATERIAL DECONTAMINATION

Method*	Surface	Action	Technique	Advantages	Disadvantages
Vacuum cleaning	Dry surfaces	Removes contaminated dust by suction.	Use conventional vacuum technique with efficient filter.	Good on dry, porous surfaces. Avoids water reactions.	All dust must be filtered out of exhaust. Machine is contaminated.
Water	All nonporous surfaces (metal, painted, plastic, etc.).	Dissolves and erodes.	For large surfaces Hose with high-pressure water at an optimum distance of 15 to 20 feet. Spray vertical surfaces at an angle of incidence of 30° to 40°; work from top to bottom to avoid recontamination. Work upwind to avoid spray.	All water equipment may be utilized. Allows operation to be carried out from a distance. Contamination may be reduced by 50%. Water equipment may be used for solutions of other decontaminating agents.	Drainage must be controlled. Not suitable for porous materials. Oiled surfaces cannot be decontaminated. Not applicable on dry contaminated surfaces (use vacuum); not applicable on porour surfaces such as wood, concrete,

*Begin with the first listed method and then proceed step by step to the more severe methods, as necessary.

AREA AND MATERIAL DECONTAMINATION--Continued

Method*	Surface	Action	Technique	Advantages	Disadvantages
Water (Cont'd)			Determine cleaning rate experimentally, if possible; otherwise, use a rate of 4 square feet per minute.		canvas, etc. Spray will be contaminated.
	All surfaces	Dissolves and erodes.	For small surfaces Blot up liquid and handwipe with water and appropriate commercial detergent.	Extremely effective if done immediately after spill and on nonporous surfaces.	Of little value in the decontamination of large areas, longstanding contaminants and porous surfaces.
Steam	Nonporous surfaces (especially painted or oiled surfaces).	Dissolves and erodes.	Work from top to bottom and from upwind. Clean surface at a rate of 4 square feet per minute. The cleaning efficiency of steam will be greatly increased by using detergents.	Contamination may be reduced approximately 90% on painted surfaces.	Steam subject to same limitations as water. Spray hazard makes the wearing of waterproof outfits necessary.
Detergents	Nonporous surfaces (metal, painted, glass, plastic, etc.).	Emulsifies contaminant and increases wetting power of water and cleaning efficiency of steam.	Rub surface 1 minute with a rag moistened with detergent solution then wipe with dry rag; use clean surface of the rag for each application. Use a power rotary brush with	Dissolves industrial film and other materials which hold contamination. Contamination may be reduced by 90%.	May require personal contact with surface. May not be efficient on longstanding contamination.

*Begin with the first listed method and then proceed step by step to the more severe methods, as necessary.

AREA AND MATERIAL DECONTAMINATION--Continued

Method*	Surface	Action	Technique	Advantages	Disadvantages
Detergents (Cont'd)			pressure feed for more efficient cleaning. Apply solution from a distance with a pressure proportioner. Do not allow solution to drip onto other surfaces. Mist application is all that is necessary.		
Complexing agents	Nonporous surfaces (especially unweathered surfaces; i.e., no rust or calcareous growth).	Forms soluble complexes with contaminated material.	Complexing agent solution should contain 3% (by weight) of agent. Spray surface with solution. Keep surface moist 30 minutes by spraying with solution periodically. After 30 minutes, flush material off with water. Complexing agents may be used on vertical and overhead surfaces by adding chemical foam (sodium carbonate or aluminum sulfate).	Holds contamination in solution. Contamination may be reduced by 75% in 4 minutes on unweathered surfaces. Easily stored; carbonates and citrates are nontoxic, noncorrosive.	Requires application for 5 to 30 minutes. Little penetrating power; of small value on weathered surfaces.

*Begin with the first listed method and then proceed step by step to the more severe methods, as necessary.

AREA AND MATERIAL DECONTAMINATION--Continued

Method*	Surface	Action	Technique	Advantages	Disadvantages
Organic solvents	Nonporous surfaces (greasy or waxed surfaces, paint or plastic finishes, etc.).	Dissolves organic materials (oil, paint, etc.).	Immerse entire unit in solvent or apply by wiping procedure (see Detergents).	Quick dissolving action. Recovery of sovlent possible by distillation.	Requires good ventilation and fire precautions. Toxic to personnel. Material bulky.
Inorganic acids	Metal surfaces (especially with porous deposits; i.e., rust or calcareous growth); circulatory pipe systems.	Dissolves porous deposits.	Use dip-bath procedure for movable items. Acid should be kept at a concentration of 1 to 2 normal (9 to 18% hydrochloric, 3 to 6% sulfuric acid). Leave on weathered surfaces for 1 hour. Flush surface with water, scrub with a water-detergent solution, and rinse. Leave in pipe circulatory system 2 to 4 hours; flush with plain water, a water-detergent solution, then again with plain water.	Corrosive action on metal and porous deposits. Corrosive action may be moderated by addition of corrosion inhibitors to solution.	Personal hazard. Wear goggles, rubber boots, gloves, and aprons. Good ventilation required because of toxicity and explosive gases. Acid mixtures should not be heated. Possibility of excessive corrosion if used without inhibitors. Sulfuric acid not effective on calcareous deposits.
Acid mixtures: hydrochloric, sulfuric, acetic, citric acids, acetates, citrates	Nonporous surfaces (especially with porous deposits); circulatory pipe systems.	Dissolves porous deposits.	Same as for inorganic acids. A typical mixture consist of 0.1 gal. hydrochloric acid, 0.2 lb sodium acetate and 1	Contamination may reduced by 90% in 1 hour (unweathered surfaces). More easily handled than inorganic acid solution.	Weathered surfaces may require prolonged treatment. Same safety precautions as required for inorganic acids.

*Begin with the first listed method and then proceed step by step to the more severe methods, as necessary.

AREA AND MATERIAL DECONTAMINATION--Continued

Method*	Surface	Action	Technique	Advantages	Disadvantages
Acid mixtures (Cont'd)			gal. water		
Caustics: lye (sodium hydroxide) calcium hydroxide potassium hydroxide	Painted surfaces (horizontal).	Softens paint (harsh method).	Allow paint-remover solution to remain on surface until paint is softened to the point where it may be washed off with water. Remove remaining paint with long-handled scrapers. Typical paint remover solution: 10 gal. water, 4 lb lye, 6 lb boiler compound, 0.75 lb cornstarch.	Minimum contact with contaminated surfaces. Easily stored.	Personal hazard (will cause burns). Reaction slow; thus, it is not efficient on vertical or overhead surfaces. Should not be used on aluminum or magnesium.
Trisodium phosphate	Painted surfaces (vertical, overhead).	Softens paint (mild method).	Apply hot 10% solution by rubbing and wiping procedure (see Detergent).	Contamination may be reduced to tolerance in one or two applications.	Destructive effect on paint. Should not be used on aluminum or magnesium.
Abrasion	Nonporous surfaces.	Removes surface.	Use conventional procedures, such as sanding, filing, and chipping; keep surface damp to avoid dust hazard.	Contamination may be reduced to as low a level as desired.	Impracticable for porous surfaces because of penetration by moisture.
Sandblasting	Nonporus surfaces.	Removes surfaces.	Keep sand wet to lessen spread of contamination.	Practical for large surface areas.	Contamination spread over area must be removed.

*Begin with the first listed method and then proceed step by step to the more severe methods, as necessary.

AREA AND MATERIAL DECONTAMINATION--Continued

Method*	Surface	Action	Technique	Advantages	Disadvantages
Sandblasting (Cont'd)			Collect used abrasive or flush away with water.		Contaminated dust is personnel hazard.
Vacuum blasting	Porous and non-porous surfaces.	Removes surface; traps and controls contaminated waste.	Hold tool flush to surface to prevent escape of contamination.	Contaminated waste ready for disposal. Safest abrasion method.	Contamination of equipment.

*Begin with the first listed method and then proceed step by step to the more severe methods, as necessary.

RULES OF THUMB

Alpha Particles

1. It requires an alpha particle of at least 7.5 MeV to penetrate the protective layer of the skin, 0.07 mm thick.
2. With 2π geometry, the surface of a thick source of tuballoy will give about 2,400 alpha cpm/cm^2; plutonium will give about 70,000 alpha cpm/μg; 16.2 g of ^{239}Pu has an activity of 1 Ci.

Beta Particles

1. When working with ^{198}Au, experience has shown that under certain conditions, the beta dose will be five times the gamma value. Therefore, only ⅙ of the total dose will be recorded by gamma dosimeters.
2. It requires a beta particle of at least 70 keV to penetrate the protective layer of the skin, 0.07 mm thick.
3. The range (R) of beta particles in g/cm^2 (thickness in cm multiplied by the density in g/cm^3) is approximately equal to the maximum energy (E) in MeV divided by 2 (i.e., $R \cong E/2$).
4. The range of beta particles in air is about 12 ft per MeV; for example, a 3 MeV beta has a range of about 36 ft in air.
5. A chamber wall thickness of 30 mg/cm^2 will reduce a flux of 1 MeV (max.) betas by 30% and a flux of 0.4 MeV betas by a factor of 4 or 5.
6. The intensity of bremsstrahlung increases approximately with the energy of the beta particle and about the square of the atomic number of the absorbing material.
7. When betas of 1 to 2 MeV pass through light materials such as water, aluminum, or glass, less than 1% of their energy is dissipated as bremsstrahlung.
8. The bremsstrahlung from 1 Ci ^{32}P aqueous solution in a glass bottle is about 1 mR/hr at 1 meter.
9. When the beta particles from a 1 Ci source of ^{90}Sr-^{90}Y are absorbed, the bremsstrahlung hazard is approximately equal to that presented by the gamma from 12 mg of radium. The average energy of the bremsstrahlung is about 300 keV.
10. For a point source of beta radiation (neglecting self- and air-absorption) of strength Ci curies, the dose rate at 1 ft is approximately equal to 300 Ci rads/hr. The variation with energy is small over a wide range.
11. Beta-ray surface dose rates with 7 mg/cm^2 filter:

Source	mrads/hr
U slug	233
UO_2 (brown oxide)	207
UF_4 (green salt)	179
$UO_2(NO_3)_2 \cdot 6H_2O$ (yellow uranyl nitrate hexahydrate)	111
UO_3 (orange oxide)	204
U_3O_8 (black oxide)	203
UO_2F_2 (cliptite or uranyl fluoride)	176
$Na_2U_2O_7$ (soda salt or sodium diuranate)	167

Gamma Rays

1. The air-scattered radiation (sky-shine) from a 100 Ci ^{60}Co source place 1 ft behind a 4-ft-high shield is about 100 mrads/hr at 6 ft from the outside of the shield.
2. Within ±20% for point source gamma emitters with energies between 0.07 and 4 MeV, the exposure rate (R/hr) at 1 ft is 6CE, where C is the number of curies and E the energy in MeV.

Neutrons

1. An approximate HVL for 1-MeV neutrons is 1.26 in. (3.2 cm) of paraffin; 2.72 in. (6.93 cm) for 5-MeV neutrons.

Miscellaneous

1. The activity of any radionuclide is reduced to less than 1% after 7 half-lives (i.e., 2^{-7} = 0.8%).
2. For material with a half-life greater than six days, the change in activity in 24 hours will be less than 10%.
3. For ^{90}Sr-^{90}Y in equilibrium, 5,000 cpm is equal to 1 mrem/hr when using a beta-gamma probe with a 30 mg/cm^2 tube.
4. There is 0.64 mm^3 of radon gas in transient equilibrium with 1 Ci of radium.
5. The exposure rate from fission products at any time (t) can be represented by: R/unit time = $I \cdot t^{-1.2}$, where I is the exposure rate at unit time, and t is in the same time units.

Taken from: Los Alamos Handbook of Radiation Monitoring, LA-1835 (3rd ed.); Health Physics Handbook - General Dynamics, OSP-379 (April 1963); and AERE, HP/L23.

Maximum permissible body burdens and maximum permissible concentrations of radionuclides in air and in water for occupational exposure

Radionuclide and type of decay		Organ of reference (critical organ in boldface)	Maximum permissible burden in total body q (μc)	Maximum permissible concentrations			
				For 40 hour week		For 168 hour week**	
				$(MPC)_w$ μc/cc	$(MPC)_a$ μc/cc	$(MPC)_w$ μc/cc	$(MPC)_a$ μc/cc
$_1H^3$(HTO or H_2^3O)(β^-)	(Sol)	**Body Tissue**	10^3	0.1	5×10^{-6}	0.03	2×10^{-6}
		Total Body	2×10^3	0.2	8×10^{-6}	0.05	3×10^{-6}
(H_2^3)	(Immersion)	**Skin**	----	----	2×10^{-3}	----	4×10^{-4}
$_6C^{14}$(CO_2)(β^-)	(Sol)	**Fat**	300	0.02	4×10^{-6}	8×10^{-3}	10^{-6}
		Total Body	400	0.03	5×10^{-6}	0.01	2×10^{-6}
		Bone	400	0.04	6×10^{-6}	0.01	2×10^{-6}
	(Immersion)	**Total Body**	----	----	5×10^{-5}	----	10^{-5}
$_{15}P^{32}$ (β^-)	(Sol)	**Bone**	6	5×10^{-4}	7×10^{-8}	2×10^{-4}	2×10^{-8}
		Total Body	30	3×10^{-3}	4×10^{-7}	9×10^{-4}	10^{-7}
		GI (LLI)	----	3×10^{-3}	6×10^{-7}	9×10^{-4}	2×10^{-7}
		Liver	50	5×10^{-3}	6×10^{-7}	2×10^{-3}	2×10^{-7}
		Brain	300	0.02	3×10^{-6}	8×10^{-3}	10^{-6}
	(Insol)	**Lung**	----	----	8×10^{-8}	----	3×10^{-8}
		GI (LLI)	----	7×10^{-4}	10^{-7}	2×10^{-4}	4×10^{-8}
$_{20}Ca^{45}$ (β^-)	(Sol)	**Bone**	30	3×10^{-4}	3×10^{-8}	9×10^{-5}	10^{-8}
		Total Body	200	2×10^{-3}	3×10^{-7}	7×10^{-4}	9×10^{-8}
		GI (LLI)	----	0.01	3×10^{-6}	4×10^{-3}	10^{-6}
	(Insol)	**Lung**	----	----	10^{-7}	----	4×10^{-8}
		GI (LLI)	----	5×10^{-3}	9×10^{-7}	2×10^{-3}	3×10^{-7}
$_{24}Cr^{51}$ (ϵ, γ)	(Sol)	**GI (LLI)**	----	0.05	10^{-5}	0.02	4×10^{-6}
		Total Body	800	0.6	10^{-5}	0.2	4×10^{-6}
		Lung	10^3	1	2×10^{-5}	0.4	8×10^{-6}
		Prostate	2×10^3	2	3×10^{-5}	0.5	10^{-5}
		Thyroid	4×10^3	3	6×10^{-5}	1	2×10^{-5}
		Kidney	8×10^3	6	10^{-4}	2	4×10^{-5}
	(Insol)	**Lung**	----	----	2×10^{-6}	----	8×10^{-7}
		GI (LLI)	----	0.05	8×10^{-6}	0.02	3×10^{-6}
$_{27}Co^{60}$ (β^-, γ)	(Sol)	**GI (LLI)**	----	10^{-3}	3×10^{-7}	5×10^{-4}	10^{-7}
		Total Body	10	4×10^{-3}	4×10^{-7}	10^{-3}	10^{-7}
		Pancreas	70	0. 02	2×10^{-6}	7×10^{-3}	6×10^{-7}
		Liver	90	0. 03	10^{-6}	9×10^{-3}	5×10^{-7}
		Spleen	200	0. 05	4×10^{-6}	0. 02	2×10^{-6}
		Kidney	200	0. 07	6×10^{-6}	0. 03	2×10^{-6}
	(Insol)	**Lung**	----	----	9×10^{-9}	----	3×10^{-9}
		GI (LLI)	----	10^{-3}	2×10^{-7}	3×10^{-4}	6×10^{-8}
$_{30}Zn^{65}$ (β^+, ϵ, γ)	(Sol)	**Total Body**	60	3×10^{-3}	10^{-7}	10^{-3}	4×10^{-8}
		Prostate	70	4×10^{-3}	10^{-7}	10^{-3}	4×10^{-8}
		Liver	80	4×10^{-3}	10^{-7}	10^{-3}	5×10^{-8}
		Kidney	100	6×10^{-3}	2×10^{-7}	2×10^{-3}	7×10^{-8}
		GI (LLI)	----	6×10^{-3}	10^{-6}	2×10^{-3}	4×10^{-7}
		Pancreas	200	7×10^{-3}	3×10^{-7}	3×10^{-3}	9×10^{-8}
		Muscle	200	0.01	4×10^{-7}	4×10^{-3}	10^{-7}
		Ovary	300	0.01	5×10^{-7}	4×10^{-3}	2×10^{-7}
		Testis	400	0.02	6×10^{-7}	6×10^{-3}	2×10^{-7}
		Bone	700	0.04	10^{-6}	0.01	4×10^{-7}
	(Insol)	**Lung**	----	----	6×10^{-8}	----	2×10^{-8}
		GI (LLI)	----	5×10^{-3}	9×10^{-7}	2×10^{-3}	3×10^{-7}
$_{33}As^{76}$ (β^-, γ)	(Sol)	**GI (LLI)**	----	6×10^{-4}	10^{-7}	2×10^{-4}	4×10^{-8}
		Total Body	20	0.4	5×10^{-6}	0.1	2×10^{-6}
		Kidney	20	0.6	8×10^{-6}	0.2	3×10^{-6}
		Liver	40	1	10^{-5}	0.4	5×10^{-6}
	(Insol)	**GI (LLI)**	----	6×10^{-4}	10^{-7}	2×10^{-4}	3×10^{-8}
		Lung	----	----	6×10^{-7}	----	2×10^{-7}

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*The abbreviations GI, S, SI, ULI, and LLI refer to gastrointestinal tract, stomach, small intestines, upper large intestine, and lower large intestine, respectively.

**It will be noted that the MPC values for the 168-hour week are not always precisely the same multiples of the MPC for the 40-hour week. Part of this is caused by rounding off the calculated values to one digit, but in some instances it is due to technical differences discussed in the ICRP report. Because of the uncertainties present in much of the biological data and because of individual variations, the differences are not considered significant. The MPC values for the 40-hour week are to be considered as basic for occupational exposure, and the values for the 168-hour week are basic for continuous exposure as in the case of the population at large.

Maximum permissible body burdens and maximum permissible concentrations of radionuclides in air and in water for occupational exposure—Continued

Radionuclide and type of decay		Organ of reference (critical organ in boldface)	Maximum permissible burden in total body $q(\mu c)$	Maximum permissible concentrations			
				For 40 hour week		For 168 hour week**	
				$(MPC)_w$ $\mu c/cc$	$(MPC)_a$ $\mu c/cc$	$(MPC)_w$ $\mu c/cc$	$(MPC)_a$ $\mu c/cc$
${}_{38}Sr^{89}$ (β^-)	(Sol)	**Bone**	4	**3×10^{-4}**	**3×10^{-8}**	**10^{-4}**	**10^{-8}**
		GI (LLI)		10^{-3}	3×10^{-7}	4×10^{-4}	9×10^{-8}
		Total Body	40	2×10^{-3}	2×10^{-7}	7×10^{-4}	6×10^{-8}
	(Insol)	**Lung**			**4×10^{-8}**		**10^{-8}**
		GI (LLI)		**8×10^{-4}**	10^{-7}	**3×10^{-4}**	5×10^{-8}
${}_{38}Sr^{90}$ (β^-)	(Sol)	**Bone**	2	**4×10^{-6}**	**3×10^{-10}**	**10^{-6}**	**10^{-10}**
		Total Body	20	10^{-5}	9×10^{-10}	4×10^{-6}	3×10^{-10}
		GI (LLI)		10^{-3}	3×10^{-7}	5×10^{-4}	10^{-7}
	(Insol)	**Lung**			**5×10^{-9}**		**2×10^{-9}**
		GI (LLI)		**10^{-3}**	2×10^{-7}	**4×10^{-4}**	6×10^{-8}
${}_{40}Zr^{95}$ (β^-, γ, e^-)	(Sol)	**GI (LLI)**		**2×10^{-3}**	4×10^{-7}	**6×10^{-4}**	10^{-7}
		Total Body	20	3	**10^{-7}**	1	**4×10^{-8}**
		Bone	30	4	2×10^{-7}	2	6×10^{-8}
		Kidney	30	4	2×10^{-7}	2	6×10^{-8}
		Liver	40	6	3×10^{-7}	2	9×10^{-8}
		Spleen	40	7	3×10^{-7}	2	10^{-7}
	(Insol)	**Lung**			**3×10^{-8}**		**10^{-8}**
		GI (LLI)		**2×10^{-3}**	3×10^{-7}	**6×10^{-4}**	10^{-7}
${}_{41}Nb^{95}$ (β^-, γ)	(Sol)	**GI (LLI)**		**3×10^{-3}**	6×10^{-7}	**10^{-3}**	**2×10^{-7}**
		Total Body	40	10	**5×10^{-7}**	4	**2×10^{-7}**
		Liver	60	20	7×10^{-7}	6	3×10^{-7}
		Kidney	60	20	8×10^{-7}	6	3×10^{-7}
		Bone	80	20	9×10^{-7}	7	3×10^{-7}
		Spleen	80	20	10^{-6}	7	3×10^{-7}
	(Insol)	**Lung**			**10^{-7}**		**3×10^{-8}**
		GI (LLI)		**3×10^{-3}**	5×10^{-7}	**10^{-3}**	2×10^{-7}
${}_{44}Ru^{106}$ (β^-, γ)	(Sol)	**GI (LLI)**		**4×10^{-4}**	**8×10^{-8}**	**10^{-4}**	**3×10^{-8}**
		Kidney	3	0.01	10^{-7}	4×10^{-3}	5×10^{-8}
		Bone	10	0.04	5×10^{-7}	0.01	2×10^{-7}
		Total Body	10	0.06	7×10^{-7}	0.02	3×10^{-7}
	(Insol)	**Lung**			**6×10^{-9}**		**2×10^{-9}**
		GI (LLI)		**3×10^{-4}**	6×10^{-8}	**10^{-4}**	2×10^{-8}
${}_{53}I^{131}$ (β^-,γ,e^-)	(Sol)	**Thyroid**	0.7	**6×10^{-5}**	**9×10^{-9}**	**2×10^{-5}**	**3×10^{-9}**
		Total Body	50	5×10^{-3}	8×10^{-7}	2×10^{-3}	3×10^{-7}
		GI (LLI)		0.03	7×10^{-6}	0.01	2×10^{-6}
	(Insol)	**GI (LLI)**		**2×10^{-3}**	**3×10^{-7}**	**6×10^{-4}**	**10^{-7}**
		Lung			**3×10^{-7}**		**10^{-7}**
${}_{55}Cs^{137}$ (β^-, γ, e^-)	(Sol)	**Total Body**	30	**4×10^{-4}**	**6×10^{-8}**	**2×10^{-4}**	**2×10^{-8}**
		Liver	40	**5×10^{-4}**	**8×10^{-8}**	**2×10^{-4}**	**3×10^{-8}**
		Spleen	50	**6×10^{-4}**	**9×10^{-8}**	**2×10^{-4}**	**3×10^{-8}**
		Muscle	50	**7×10^{-4}**	**10^{-7}**	**2×10^{-4}**	**4×10^{-8}**
		Bone	100	10^{-3}	2×10^{-7}	5×10^{-4}	7×10^{-8}
		Kidney	100	10^{-3}	2×10^{-7}	5×10^{-4}	8×10^{-8}
		Lung	300	5×10^{-3}	6×10^{-7}	2×10^{-3}	2×10^{-7}
		GI (SI)		0.02	5×10^{-6}	8×10^{-3}	2×10^{-6}
	(Insol)	**Lung**			**10^{-8}**		**5×10^{-9}**
		GI (LLI)		**10^{-3}**	2×10^{-7}	**4×10^{-4}**	8×10^{-8}
${}_{58}Ce^{144}$ (α, β^-, γ)	(Sol)	**GI (LLI)**		**3×10^{-4}**	8×10^{-8}	**10^{-4}**	3×10^{-8}
		Bone	5	0.2	**10^{-8}**	0.08	**3×10^{-9}**
		Liver	6	0.3	**10^{-8}**	0.1	4×10^{-9}
		Kidney	10	0.5	2×10^{-8}	0.2	7×10^{-9}
		Total Body	20	0.7	3×10^{-8}	0.3	10^{-8}
	(Insol)	**Lung**			**6×10^{-9}**		**2×10^{-9}**
		GI (LLI)		**3×10^{-4}**	6×10^{-8}	**10^{-4}**	2×10^{-8}
${}_{61}Pm^{147}$ (α, β^-)	(Sol)	**GI (LLI)**		**6×10^{-3}**	10^{-6}	**2×10^{-3}**	5×10^{-7}
		Bone	60	1	**6×10^{-8}**	0.5	**2×10^{-8}**
		Kidney	200	4	2×10^{-7}	2	7×10^{-8}
		Total Body	300	7	3×10^{-7}	2	10^{-7}
		Liver	300	8	4×10^{-7}	3	10^{-7}
	(Insol)	**Lung**			**10^{-7}**		**3×10^{-8}**
		GI (LLI)		**6×10^{-3}**	10^{-6}	**2×10^{-3}**	4×10^{-7}

Maximum permissible body burdens and maximum permissible concentrations for radionuclides in air and in water for occupational exposure—Continued

Radionuclide and type of decay		Organ of reference (critical organ in boldface)	Maximum permissible burden in total body q(μc)	Maximum permissible concentrations			
				For 40 hour week		For 168 hour week**	
				$(MPC)_w$ μc/cc	$(MPC)_a$ μc/cc	$(MPC)_w$ μc/cc	$(MPC)_a$ μc/cc
$_{73}$Ta^{182} (β^-, γ)	(Sol)	**GI (LLI)**		10^{-3}	3×10^{-7}	4×10^{-4}	9×10^{-8}
		Liver	7	0.9	4×10^{-8}	0.3	10^{-8}
		Kidney	20	2	8×10^{-8}	0.7	3×10^{-8}
		Total Body	20	2	9×10^{-8}	0.7	3×10^{-8}
		Spleen	30	4	10^{-7}	1	5×10^{-8}
		Bone	50	6	3×10^{-7}	2	9×10^{-8}
	(Insol)	**Lung**			2×10^{-8}		7×10^{-9}
		GI (LLI)		10^{-3}	2×10^{-7}	4×10^{-4}	7×10^{-8}
$_{77}$Ir^{192} (β^-, γ)	(Sol)	GI (LLI)		10^{-3}	3×10^{-7}	4×10^{-4}	9×10^{-8}
		Kidney	6	4×10^{-3}	10^{-7}	10^{-3}	4×10^{-8}
		Spleen	7	4×10^{-3}	10^{-7}	10^{-3}	5×10^{-8}
		Liver	8	5×10^{-3}	2×10^{-7}	2×10^{-3}	6×10^{-8}
		Total Body	20	0.01	4×10^{-7}	4×10^{-3}	10^{-7}
	(Insol)	**Lung**			3×10^{-8}		9×10^{-9}
		GI (LLI)		10^{-3}	2×10^{-7}	4×10^{-4}	6×10^{-8}
$_{79}$Au^{198} (β^-, γ)	(Sol)	**GI (LLI)**		2×10^{-3}	3×10^{-7}	5×10^{-4}	10^{-7}
		Kidney	20	0.07	3×10^{-6}	0.02	9×10^{-7}
		Total Body	30	0.1	4×10^{-6}	0.04	2×10^{-6}
		Spleen	60	0.2	8×10^{-6}	0.07	3×10^{-6}
		Liver	80	0.3	10^{-5}	0.1	4×10^{-6}
	(Insol)	**GI (LLI)**		10^{-3}	2×10^{-7}	5×10^{-4}	8×10^{-8}
		Lung			6×10^{-7}		2×10^{-7}
$_{86}$Rn^{222}† (α, β, γ)		**Lung**			3×10^{-8}		10^{-8}
$_{88}$Ra^{226} (α, β^-, γ)	(Sol)	**Bone**	0.1	4×10^{-7}	3×10^{-11}	10^{-7}	10^{-11}
		Total Body	0.2	6×10^{-7}	5×10^{-11}	2×10^{-7}	2×10^{-11}
		GI (LLI)		10^{-3}	3×10^{-7}	5×10^{-4}	10^{-7}
	(Insol)	**Lung**			5×10^{-11}		2×10^{-11}
		GI (LLI)		9×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
$_{92}$U^{235} (α, β^-, γ)	(Sol)	**GI (LLI)**		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
		Kidney	0.03	0.01	5×10^{-10}	4×10^{-3}	2×10^{-10}
		Bone	0.06	0.01	6×10^{-10}	5×10^{-3}	2×10^{-10}
		Total Body	0.4	0.04	2×10^{-9}	0.01	6×10^{-10}
	(Insol)	**Lung**			10^{-10}		4×10^{-11}
		GI (LLI)		8×10^{-4}	10^{-7}	3×10^{-4}	5×10^{-8}
$_{92}$U^{238} (α, γ, e$^-$)	(Sol)	**GI (LLI)**		10^{-3}	2×10^{-7}	4×10^{-4}	8×10^{-8}
		Kidney	5×10^{-3}	2×10^{-3}	7×10^{-11}	6×10^{-4}	3×10^{-11}
		Bone	0.06	0.01	6×10^{-10}	5×10^{-3}	2×10^{-10}
		Total Body	0.5	0.04	2×10^{-9}	0.01	6×10^{-10}
	(Insol)	**Lung**			10^{-10}		5×10^{-11}
		GI (LLI)		10^{-3}	2×10^{-7}	4×10^{-4}	6×10^{-8}
$_{94}$Pu^{239} (α, γ)	(Sol)	**Bone**	0.04	10^{-4}	2×10^{-12}	5×10^{-5}	6×10^{-13}
		Liver	0.4	5×10^{-4}	7×10^{-12}	2×10^{-4}	2×10^{-12}
		Kidney	0.5	7×10^{-4}	9×10^{-12}	2×10^{-4}	3×10^{-12}
		GI (LLI)		8×10^{-4}	2×10^{-7}	3×10^{-4}	6×10^{-8}
		Total Body	0.4	10^{-3}	10^{-11}	3×10^{-4}	5×10^{-12}
	(Insol)	**Lung**			4×10^{-11}		10^{-11}
		GI (LLI)		8×10^{-4}	2×10^{-7}	3×10^{-4}	5×10^{-8}

†The daughter isotopes of Rn^{220} and Rn^{222} are assumed present to the extent they occur in unfiltered air. For all other isotopes the daughter elements are not considered as part of the intake and if present must be considered on the basis of the rules for mixtures.

Maximum permissible concentration of unidentified radionuclides in water, (MPCU)$_w$ *values*, for continuous occupational exposure*

Limitations	μc/cm^3 of water**
If no one of the radionuclides Sr^{90}, I^{126}, I^{129}, I^{131}, Pb^{210}, Po^{210}, At^{211}, Ra^{223}, Ra^{224}, Ra^{226}, Ra^{228}, Ac^{227}, Th^{230}, Pa^{231}, Th^{232}, and Th-nat is present, then the (MPCU)$_w$ is	3×10^{-5}
If no one of the radionuclides Sr^{90}, I^{129}, Pb^{210}, Po^{210}, Ra^{223}, Ra^{226}, Ra^{228}, Pa^{231}, and Th-nat is present, then the (MPCU)$_w$ is	2×10^{-5}
If no one of the radionuclides Sr^{90}, I^{129}, Pb^{210}, Ra^{226}, and Ra^{228} is present, then the (MPCU)$_w$ is	7×10^{-6}
If neither Ra^{226} nor Ra^{228} is present, then the (MPCU)$_w$ is	10^{-6}
If no analysis of the water is made, then the (MPCU)$_w$ is	10^{-7}

*Each (MPCU)$_w$ value is the smallest value of (MPC)$_w$ in table 1 for radionuclides other than those listed opposite the value. Thus these (MPCU)$_w$ values are permissible levels for continuous occupational exposure (168 hr/wk) for any radionuclide or mixture of radionuclides where the indicated isotopes are not present (i.e., where the concentration of the radionuclide in water is small compared with the (MPC)$_w$ value for this radionuclide). The (MPCU)$_w$ may be much smaller than the more exact maximum permissible concentration of the material, but the determination of this (MPC)$_w$ requires identification of the radionuclides present and the concentration of each.

**Use one-tenth of these values for interim application in the neighborhood of a controlled exposure area.

Maximum permissible concentration of unidentified radionuclides in air, (MPCU)$_a$ *values*, for continuous occupational exposure*

Limitations	μc/cm^3 of air**
If there are no α-emitting radionuclides and if no one of the β-emitting radionuclides Sr^{90}, I^{129}, Pb^{210}, Ac^{227}, Ra^{228}, Pa^{230}, Pu^{241}, and Bk^{249} is present, then the (MPCU)$_a$ is	10^{-9}
If there are no α-emitting radionuclides and if no one of the β-emitting radionuclides Pb^{210}, Ac^{227}, Ra^{228}, and Pu^{241} is present, then the (MPCU)$_a$ is	10^{-10}
If there are no α-emitting radionuclides and if the β-emitting radionuclide Ac^{227} is not present, then the (MPCU)$_a$ is	10^{-11}
If no one of the radionuclides Ac^{227}, Th^{230}, Pa^{231}, Th^{232}, Th-nat, Pu^{238}, Pu^{239}, Pu^{240}, Pu^{242}, and Cf^{249} is present, then the (MPCU)$_a$ is	10^{-12}
If no one of the radionuclides Pa^{231}, Th-nat, Pu^{239}, Pu^{240}, Pu^{242}, and Cf^{249} is present, then the (MPCU)$_a$ is	7×10^{-13}
If no analysis of the air is made, then the (MPCU)$_a$ is	4×10^{-13}

*Each (MPCU)$_a$ value is the smallest value of (MPC)$_a$ in table 1 for radionuclides other than those listed opposite the value. Thus these (MPCU)$_a$ values are permissible levels for continuous occupational exposure (168 hr/wk) for any radionuclide or mixture of radionuclides where the indicated isotopes are not present (i.e., where the concentration of the radionuclide in air is small compared with the (MPC)$_a$ value for this radionuclide). The (MPCU)$_a$ value may be much smaller than the more exact maximum permissible concentration of the material, but the determination of this (MPC)$_a$ requires identification of the radionuclides present and the concentration of each.

**Use one-tenth of these values for interim application in the neighborhood of a controlled exposure area.

*These radionuclides were selected from National Bureau of Standards Handbook 69 (for sale by U. S. Government Printing Office, Washington 25, D. C.). This publication lists (for all radionuclides) the recommendations of the National Committee on Radiation Protection and Measurements for Maximum Permissible Body Burdens and Maximum Permissible Concentrations in Air and Water for Occupational Exposure. The handbook should be consulted for MPC and MPBB values of other nuclides or for information on derivation and limitations of these values.

RADIATION PROTECTION GUIDES

Type of Exposure	Condition	Dose (rem)
Radiation worker:		
(a) Whole body, head and trunk, active blood-forming organs, gonads, or lens of eye	Accumulated dose	5 times number of years beyond age 18
	13 weeks	3
(b) Skin of whole body and thyroid	Year	30
	13 weeks	10
(c) Hands and forearms, feet and ankles	Year	75
	13 weeks	25
(d) Bone	Body burden	0.1 µCi of ^{226}Ra or its biological equivalent
(e) Other organs	Year	15
	13 weeks	5
Population:		
(a) Individual	Year	0.5 (whole body)
(b) Average	30 years	5 (gonads)

NOTE: See FRC Report No. 1, May 1960, for details.

QUALITY FACTOR vs. LINEAR ENERGY TRANSFER

LET (keV/micrometer in water)	QF
3.5 or less	1
3.5-7.0	1- 2
7.0-23	2- 5
23-53	5-10
53-175	10-20

QUALITY FACTOR VALUES

Radiation	QF
Gamma rays from radium in equilibrium (0.5 mm platinum filter	1
X Rays	1
Beta rays and electrons; > 0.03 MeV	1
Beta rays and electrons; < 0.03 MeV	1.7
Thermal neutrons	3
Fast neutrons	10
Protons	10
Alpha rays	10
Heavy ions	20

STANDARD MAN

The information on pages 212, 213, and 214 is from data supplied by Dr. Isabel H. Tipton, University of Tennessee, Knoxville.

The data on pages 215, 216, and 217 is taken from sources too numerous to reference. Inquiries regarding specific details should be addressed to the Radiological Health Handbook Committee.

NOTE: Numbers may differ from ICRP Committee II Report. Those using this information on Standard Man should be aware of the efforts of the ICRP Subcommittee on Standard Man. Reports of this Committee should be noted and pen and ink changes made on pages 212 through 217, as necessary.

WEIGHTS OF ORGANS AND TISSUES OF STANDARD MAN

Tissue or Organ	Mass (grams)		Total Body (%)	
Adipose tissue	15000		21	
Subcutaneous*		7500		11
Other separable*		5000		7.1
Interstitial	800		1.1	
Yellow marrow (added with skeleton)	1700		2.4	
Adrenals (2)*		14		0.02
Aorta*		100		0.14
Contents (blood)*		190		0.27
Blood	5500		7.8	
Plasma	3200		4.6	
Erythrocytes	2300		3.2	
Blood vessels* (not including aorta and pulmonary)		200		0.29
Contents (blood)*		2500		3.6
Cartilage	2000		2.9	
Skeletal cartilage	1700		2.4	
Non-skeletal cartilage*		300		0.43
Dense connective tissue	4000		5.7	
Tendons and ligaments*		2000		2.9
Other connective tissue	2000		2.9	
Eyes (2)*		15		0.02
Lenses (2)	0.5		--	
Gall bladder*		10		0.01
Contents (bile)*		63		0.09
G.I. tract*		1200		1.7
Esophagus	50		0.07	
Stomach	150		0.21	
Intestine	1000		1.4	
Small	500		0.71	
Upper large	250		0.36	
Lower large	250		0.36	
Contents of G.I. tract* (food plus digestive fluids)		1000		1.4
Hair*		20		0.03
Heart*		300		0.50
Contents (blood)*		390		0.56
Kidneys (2)*		310		0.44
Larynx*		15		0.02
Liver*		1800		2.6
Lungs (2)*		1000		1.4
Parenchyma	580		0.83	
Pulmonary blood	480		0.61	
Lymph nodes*		250		0.36

WEIGHT OF ORGANS AND TISSUES OF STANDARD MAN--Continued

Tissue or Organ	Mass (grams)		Total Body (%)	
Miscellaneous* (by difference)		590		0.84
Soft tissue (nasopharynx, etc.)	240		0.34	
Fluids (synovial, pleural, etc.)	350		0.50	
Muscle (skeletal)*		28000		40.0
Nails*		10		0.01
Nervous system - central				
Brain*		1400		2.0
Spinal cord*		30		0.04
Contents - cerebrospinal fluid*		120		0.17
Pancreas*		100		0.14
Parathyroids (4)*		0.12		--
Pineal*		0.2		--
Pituitary*		0.6		--
Prostate*		16		0.023
Salivary glands (6)*		85		0.12
Skeleton*		10000		14
Bone	5000		7.2	
Cortical	4000		5.7	
Trabecular	1000		1.4	
Red marrow	1300		1.9	
Yellow marrow	1700		2.4	
Cartilage	1700		2.4	
Blood	300		0.43	
Skin*		4900		7.0
Epidermis	500		0.71	
Dermis	4400		6.3	
Hypodermis (see adipose tissue)	7500		--	
Spleen*		180		0.26
Teeth*		46		0.065
Testes (2)*		60		0.085
Thymus*		20		0.028
Thyroid*		16		0.023
Tongue		70		0.10
Tonsils (2)*		4		0.006
Trachea*		15		0.021
Ureters (2)*		16		0.023
Urethra*		2		0.003
Urinary bladder*		45		0.064
Contents (urine)*		102		0.14
Total Body		70000		100

*Sum = total body (including the second column figures under "Mass" and "Total Body").

STANDARD MAN: TOTAL BODY CONTENT FOR SOME ELEMENTS

Element	Amount (grams)	Percent of Total Body	Element	Amount (grams)	Percent of Total Body
Oxygen	43000	61	Bromine	0.20	0.00029
Carbon	16000	23	Lead	0.12	0.00017
Hydrogen	7000	10	Copper	0.072	0.00010
Nitrogen	1800	2.6	Aluminum	0.061	0.00009
Calcium	1000	1.4	Cadmium	0.050	0.00007
Phosphorus	720	1.0	Boron	<0.048	0.00007
Sulfur	140	0.20	Barium	0.022	0.00003
Potassium	140	0.20	Tin	<0.017	0.00002
Sodium	100	0.14	Manganese	0.012	0.00002
Chlorine	95	0.12	Nickel	0.010	0.00001
Magnesium	19	0.027	Gold	<0.010	0.00001
Silicon	18	0.026	Molybdenum	<0.0093	0.00001
Iron	4.2	0.006	Chromium	<0.0066	0.000009
Fluorine	2.6	0.0037	Cesium	0.0015	0.000002
Zinc	2.3	0.0033	Cobalt	0.0015	0.000002
Rubidium	0.32	0.00046	Uranium	0.0007	0.000001
Strontium	0.32	0.00046	Beryllium	0.000036	----
			Radium	3.1×10^{-11}	----

SPECIFICATIONS FOR STANDARD MAN

	Adult Man	Adult Woman	Child 10 years	Infant 1 year	Newborn
Weight (kg)	70	58	--	--	3.4
Length (cm)	170	160	--	--	50
Surface Area (cm^2)	18000	16000	--	--	2200
Specific Gravity	1.07	1.04	--	--	--
Total Body Water (ml/kgW)	600	500	--	--	--
Extracellular Water	260	200	--	--	--
Intracellular	340	300	--	--	--
Total Blood Volume (ml)	5200	3900	--	--	--
Red Cell Volume (ml)	2200	1350	--	--	--
Plasma Volume (ml)	3050	2500	--	--	--
Total Blood Weight (g)	5500	4100	--	--	--
Red Cell Weight (g)	2400	1500	--	--	--
Plasma Weight (g)	3100	2600	--	--	--
Total Adipose Tissue (kg)	15	19	--	--	--
Subcutaneous	7.5	13	--	--	--
Sparable	5.0	4	--	--	--
Yellow Marrow	1.7	1.4	--	--	--
Interstitial	0.8	0.6	--	--	--
Total Connective Tissue (g)	5100	4100	--	--	--
Cartilage	2500	2000	--	--	--
Tendons and Fascia	850	700	--	--	--
Other	1700	1400	--	--	--
Total Fat (kg)	13.5	15	--	--	--
Nonessential	12	13.8	--	--	--
Essential	1.5	1.2	--	--	--
Hair (g)	20	300	--	--	--
Nails (g)	3	3	--	--	--
Skeletal Muscle (kg)	28	17	--	--	--
Total Skin (g)	4900	3500	--	--	--
Epidermis	500	400	--	--	--
Dermis	4400	3100	--	--	--
Hypodermis	7500	13000	--	--	--
Resting Metabolic Rate (cal/min-kg)	17	16	25	35	--
Oxygen Inhaled (g)	920	640	--	--	--
Carbon Dioxide Exhaled (g)	1000	700	--	--	--
Total Lung Capacity (liters)	5.6	4.4	--	--	--
Functional Residual	2.2	1.8	--	--	--
Vital	4.3	3.3	--	--	--
Dead Space	0.160	0.130	--	--	--
Minute Volume (liters/min)					
Resting	7.5	6.0	4.8	1.5	0.5
Light Activity	20	19	13	4.2	1.5

SPECIFICATIONS FOR STANDARD MAN--Continued

	Adult Man	Adult Woman	Child 10 years	Infant 1 year	Newborn
Total Air Breathed (liters)	22800	21120	14784	4700	780
8 hr. working (light)	9600	9120	6240	3500 (10 hr)	90 (1 hr)
8 hr. nonoccupational	9600	9120	6240	--	--
8 hr. resting	3600	2880	2304	1200 (14 hr)	690 (23 hr)
Dietary Intake (g)					
Protein	95	66	--	--	--
Carbohydrate	390	270	--	--	--
Fat	120	85	--	--	--
Water in Diet	1000	700	--	--	--
Water in Fluid	1700	1200	--	--	--
Water in Oxidation	300	200	--	--	--
Elements					
Carbon	300	210	200	--	--
Hydrogen	350	245	230	--	--
Nitrogen	15	10	10	--	--
Oxygen	2600	1800	1700	--	--
Milk Consumption (ml/day)	300	200	~470	~1000	--
Fecal Components (g)					
Weight	135	--	85	24	--
Water	105	--	66	19	--
Solids	30	--	19	5	--
Ash	17	--	6	1	--
Fats	5	--	4	3	--
Nitrogen	1.5	--	1	0.3	--
Other Substances	6.5	--	8	0.7	--
Elements					
Carbon	6.7	--	4.2	1.2	--
Hydrogen	13	--	8.6	2.5	--
Nitrogen	1.5	--	1.0	0.3	--
Oxygen	98	--	62	17	--
Urine (g)					
Volume (ml)	1400	--	1000	450	--
Specific Gravity	1.001-1.030	--	--	1.002-1.019	--
Solids	60	--	47	19	19
Urea	22	--	--	--	--
"Sugars"	1	--	--	--	--
Carbonates	2	--	--	--	--
Elements					
Nitrogen	15	--	11	5	--
Hydrogen	160	--	110	50	--
Oxygen	1300	--	970	420	--
Carbon	5	--	3	0.5	--

SPECIFICATIONS FOR STANDARD MAN--Continued

	Adult Man	Adult Woman	Child 10 years	Infant 1 year	Newborn
Water Balance (ml/day)					
Total Gains	3000	2100	2000	--	--
Fluid Intake	1950	1400	1400	--	--
Milk	300	200	450	--	--
Tap Water	150	100	200	--	--
Others	1500	1100	750	--	--
In Food	700	450	400	--	--
By Oxidation in Food	350	250	200	--	--
Total Losses (ml/day)	3000	2100	2000	--	--
Urine	1400	1000	1000	--	--
Feces	100	80	70	--	--
Insensible Loss	850	600	580	--	--
Sweat	650	420	350	--	--

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SECTION IV

ELEMENTS IN "TABLE OF ISOTOPES"

(The numbers in parentheses refer to the Decay Scheme pages)

Element	Sym.	Z	Page
Actinium	Ac	89	365
Aluminum	Al	13	237
Americium	Am	95	373
Antimony	Sb	51	290
Argon	Ar	18	241 (384)
Arsenic	As	33	256
Astatine	At	85	359
Barium	Ba	56	303 (400)
Berkelium	Bk	97	376
Beryllium	Be	4	232
Bismuth	Bi	83	354 (406)
Boron	B	5	232
Bromine	Br	35	259
Cadmium	Cd	48	283
Calcium	Ca	20	243 (385)
Californium	Cf	98	376
Carbon	C	6	233 (382)
Cerium	Ce	58	307 (401)
Cesium	Cs	55	301 (399)
Chlorine	Cl	17	240
Chromium	Cr	24	246 (386)
Cobalt	Co	27	249 (388)
Copper	Cu	29	251 (390)
Curium	Cm	96	374
Dysprosium	Dy	66	321
Einsteinium	Es	99	377
Erbium	Er	68	325
Europium	Eu	63	315
Fermium	Fm	100	378
Fluorine	F	9	235
Francium	Fr	87	363
Gadolinium	Gd	64	317
Gallium	Ga	31	253
Germanium	Ge	32	254
Gold	Au	79	345 (405)
Hafnium	Hf	72	332
Helium	He	2	231
Holmium	Ho	67	322
Hydrogen	H	1	231 (382)
Indium	In	49	285 (396)
Iodine	I	53	297 (396)
Iridium	Ir	77	340 (403)
Iron	Fe	26	248 (386)
Krypton	Kr	36	261 (391)
Kurchatovium*	Ku	104	380
Lanthanum	La	57	306 (400)
Lawrencium	Lr	103	380
Lead	Pb	82	352 (406)
Lithium	Li	3	231
Lutecium	Lu	71	330
Magnesium	Mg	12	236
Manganese	Mn	25	247 (386)
Mendelevium	Md	101	379
Mercury	Hg	80	347 (404)
Molybdenum	Mo	42	272 (394)
Neodymium	Nd	60	310
Neon	Ne	10	235
Neptunium	Np	93	371
Neutron	n	0	231
Nickel	Ni	28	250 (389)
Niobium	Nb	41	270 (393)
Nitrogen	N	7	233
Nobelium	No	102	379
Osmium	Os	76	339
Oxygen	O	8	234
Palladium	Pd	46	279
Phosphorus	P	15	238 (383)
Platinum	Pt	78	343
Plutonium	Pu	94	372 (409)
Polonium	Po	84	356 (406)
Potassium	K	19	241 (384)
Praseodymium	Pr	59	309 (402)
Promethium	Pm	61	312
Protactinium	Pa	91	368 (408)
Radium	Ra	88	364 (406)
Radon	Rn	86	361 (406)
Rhenium	Re	75	337
Rhodium	Rh	45	277
Rubidium	Rb	37	263 (391)
Ruthenium	Ru	44	276 (395)
Samarium	Sm	62	313
Scandium	Sc	21	244
Selenium	Se	34	257
Silicon	Si	14	238
Silver	Ag	47	281
Sodium	Na	11	236 (382)
Strontium	Sr	38	265 (392)
Sulfur	S	16	239 (384)
Tantalum	Ta	73	334
Technetium	Tc	43	274
Tellurium	Te	52	293
Terbium	Tb	65	318
Thallium	Tl	81	350
Thorium	Th	90	366 (408)
Thulium	Tm	69	326
Tin	Sn	50	288
Titanium	Ti	22	245
Uranium	U	92	369 (407)
Vanadium	V	23	245
Wolfram†	W	74	335
Xenon	Xe	54	299 (398)
Ytterbium	Yb	70	328
Yttrium	Y	39	267 (392)
Zinc	Zn	30	252 (390)
Zirconium	Zr	40	269 (393)

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* Suggested name.

† Also called tungsten.

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Table of Isotopes

The material in this section is taken from the book, "Table of Isotopes," by C. M. Lederer, J. M. Hollander, and I. Perlman, 6th edition, published by John Wiley and Sons, Inc., New York, 1967.

Table I is an exact reproduction of Table I of the above publication. The bibliography referred to is not reproduced here.

Table II, as presented here, consists of specially selected decay schemes.

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TABLE I. RADIOISOTOPE DATA

This table displays all radioactive and stable nuclei arranged according to atomic number with increasing mass number for each element. The criterion for the selection of data on each radioactive isotope has been that of identifying it in terms of its rate and mode of decay, principal radiations, and how it is prepared. The data are arranged in six columns, each of which receives comment below.

Note on references. References to the original publications are coded according to the first author and the year of publication. Example: the symbol AagP57 permits the appropriate journal reference to be found readily in the alphabetical listing in the bibliography. If the reader is already familiar with the work, he will recognize this symbol as referring to a 1957 paper of P. Aagard and co-workers.

Column 1—Isotope. The symbols here give the isotopic assignments in usual form. Stable or long-lived naturally occurring isotopes are indicated by underlining. The superscript *m* following the mass number refers to a metastable, or isomeric, state which has a sufficiently long half-life to be investigated independently from its ground state. Likewise, the designations m_1 and m_2 refer to several metastable states of a nucleus. When it is not established which of several isomers is the ground state, each isomer is referred to by the same symbol without the *m*; for example, Eu^{150} (12.6 h) and Eu^{150} (≈5 y).

Generally, isomeric states are included in Table I if their half-lives exceed ≈1 s; exceptions are made for a few chemically or genetically identified isomers of somewhat shorter half-life. The half-lives of many short-lived excited states have been measured because of their importance to nuclear structure. They are not listed in Table I as isomeric states but can be found in Table II, under the listing of the ground state of the appropriate isotope.

The historical names for the naturally occurring activities Th^{232}, U^{235}, U^{238}, and their descendents are given in Column 1 beneath the isotopic assignment.

Column 2—Half-life. An attempt has been made to list the most accurate value first, usually inferred from the stated precision. Unless otherwise stated, the value listed is the total half-life, which is the entity measured when the decay is followed. When a nucleus has more than one mode of decay, the percentage of each mode is given in Column 3.

An exception is made for those heavy nuclei that have measurable spontaneous-fission rates. The appropriate spontaneous-fission half-life is listed in Column 2 and designated by the symbol $t_{1/2}(SF)$. In a number of cases no radioactivity has been observed, although sought, and the lower limit of the half-life is listed for the mode of decay looked for ($\beta \equiv \beta$ decay, $\beta\beta \equiv$ simultaneous emission of two β particles, EC $\equiv$ electron capture, $\alpha \equiv \alpha$ decay).

If there is no special designation after the listed half-life, it may be assumed that the determination was made by direct decay measurement. (For the very short lifetimes the timing is done electronically rather than mechanically.) For indirect half-life determinations, the methods are described by the following symbols:

sp act (+ mass spect)	Determination of disintegration rate of a sample containing a known weight of the active substance (mass spectographic analysis of the sample to correct for other isotopes present).
genet	Decay of parent substance, followed by the periodic removal of a decay product which can be measured. (genet ≡ genetic relation).
yield	Measurement of radioactivity from a sample containing a number of atoms calculated according to the expected yield of the reaction by which it was produced.
est	In a few instances (α emitters) the half-lives are estimated from the energies of the measured radiations.
delay coinc	Several isotopes are short-lived products of longer lived parents. Those whose half-lives are in the millisecond range or shorter were measured by recording the time-interval distribution between the emissions from the parent substance and the daughter product.

Column 3—Type of decay. Because many classes of data are included in this column, the entry denoting *type of decay* is preceded by the special symbol for radiation, ☢ . When the mode of decay is enclosed in square brackets, that mode is inferred or assumed, not directly measured. When independent modes of decay have been measured, the branching ratios are entered as percentages. Symbols used are

β^-	Negative β-particle (negatron) emission
β^+	Positive β-particle (positron) emission
EC	Orbital electron capture
α	Alpha-particle emission
IT	Isomeric transition (decay from an excited metastable state to a lower state)
SF	Spontaneous fission. Listings are made here only if the branching is about 1% or more. For others the

partial half-lives for spontaneous fission are entered in Column 2.

n Neutron emission from excited states promptly following β decay to those levels. Entry is made in conjunction with the β emitter.

p Proton emission from excited states promptly following β decay to those levels. Entry is made in conjunction with the β emitter.

Wherever experimenters have searched for and failed to find a particular mode of decay, the indication is, for example, "no β^+." Experimental limits are given but no limits predicted from theory. Limits of detection in cases in which *no* radioactivity has been observed are listed in Column 2 in terms of a lower limit on the half-life.

Among the α emitters in the heavy element region closed decay cycles may almost always be employed to determine whether a nucleus is β stable without resort to specific experimental evidence. Those that are known to be β stable are designated by the entry *β stable (cons energy)* to indicate that the principle of conservation of energy underlies the calculations.

Percent abundance. The isotopic abundances listed are on an "atom percent" basis and refer to the elements as they exist in the earth's crust. Some of the light elements have variations in composition outside the accuracy of determination. For these elements ranges are given with references to the publications in which the variations are discussed. Particular values are also given for some specific sources of the specimens analyzed.

Isotopic mass. The atomic masses of all species measured by mass spectrometry or calculated from reaction energies are entered in the form of the mass excess, $\triangle(\equiv M\text{-}A)$; the unified mass scale ($\triangle(C^{12}) = 0$) is employed. It will be noted that these mass excess values are in units of million electron volts. Most of the data were taken from the compilation of Mattauch, Theile, and Wapstra (MTW), which should be consulted for the accuracy attached to them. The experimental decay energies of radioactive species on which many of their masses are based may be found as Q values on the decay schemes in Table II.

Cross sections. It is not possible to list all known reaction cross sections in a table such as this, but values are given for the neutron-capture reaction (σ_c) and for neutron-induced fission (σ_f) in units of 10^{-24} cm^2 (barns). Most of the cross sections shown are taken from a compilation by D. T. Goldman and M. D. Goldberg (GoldmDT64) and refer to neutrons with velocity 2200 meters/sec. The reader is cautioned to note that many nuclei have strong resonances in the epithermal region, and because "thermal" reactors contain epithermal neutrons in the irradiation positions the effective cross sections for certain nuclei can be larger than those indicated here.

Our symbol σ_c refers to that part of the capture reaction in which fission does not result. Unless otherwise stated, σ_c applies to the (n, γ) reaction. For some light nuclei the principal reaction with thermal neutrons may be (n, p) or some other reaction. Wherever such a reaction is referred to, it is so indicated.

Column 4—class; identification; genetic relationships. Class. The degree of certainty of each isotopic assignment is indicated by a letter according to the following code:

A Element and mass number certain
B Element certain and mass number probable
C Element probable and mass number certain or probable
D Element certain but mass number not well established
E Element probable and mass number not well established
F Insufficient evidence
G Probably in error.

These "ratings" should not be read as levels of confidence in the experiments but rather as an indication of the limitations of the experiments as they relate isotopic assignments to the radioactive properties discerned. In some instances a simple cross bombardment (production of an isotope in two or more ways) results in an unambiguous assignment. In others much more elaborate experiments are insufficient. Among the factors that can limit the certainty of an assignment based on its means of production are targets of mixed isotopic composition, low cross sections, the possibility of isomerism, similarity of properties to other isotopes, and absence of knowledge of neighboring isotopes.

Identification. The means by which the isotopic assignments were established are tabulated next. In general, several references are combined, and among them the first refers to the discovery of the isotope (except for classical natural radioactivities). Indication of the experimental methods used in making the various assignments may be had from the following symbols:

chem Chemical separations establishing the chemical identity (atomic number) of the isotope.

genet Established decay relationship (by chemical or other means) with another isotope whose mass assignment is known.

excit Refers broadly to energy considerations in the production of the isotope, some of which are
  (1) excitation-function or yield experiments to establish the nuclear reaction which produced the isotope;
  (2) limitation of products formed by limiting the energy of bombarding particles;
  (3) making use of a calculated Q value;
  (4) in a few instances use of fission-yield data to limit mass assignments.

cross bomb Arrival at an assignment by producing the isotope in different ways.

n-capt Key evidence supplied by production with slow neutrons from which it is usually inferred that the (n, γ) reaction was observed.

sep isotopes The use of target elements enriched or depleted in a particular isotope.

mass spect Mass number determined by mass spectrometry.

decay charac Identification of predicted decay properties such as decay energy or energy-level pattern.

genet energy levels Energy levels of daughter nucleus agree with those from decay of another isotope whose isotopic assignment and mode of decay are known or with levels observed in nuclear reactions.

atomic level spacing Atomic number of decay product established by measuring the characteristic energy differences between internal-conversion electron lines from a particular γ transition converted in different shells.

critical abs Identification of the atomic number of the decay product by critical absorption of X-rays accompanying the decay process.

Genetic relationships. Below the designation of how the isotope was identified are listed specifically those genetic (or parent-daughter) relations established by chemical or physical separation and radiochemical characterization of the daughter atoms. Among other things, this list also gives the reader some warning that radiations from decay products may be present with those from the parent.

Column 5—Major radiations. The purpose of this list is to acquaint the reader at a glance with the principal radiations associated with each isotope. The radiations shown will often be sufficient to identify the isotope. Because it is the purpose here to delineate what is actually seen when a particular isotope is encountered, the X-rays and annihilation radiation (0.511-MeV γ rays from the annihilation of positrons, designated by the symbol $\gamma\pm$), are indicated if they are prominent in the electromagnetic spectrum. If essentially all the decays proceed by positron emission, the notation 0.511 (200%, $\gamma\pm$) will appear. (Several per cent of the positrons annihilate in flight, which means that a corresponding number of photons will not have 0.511 MeV energy.) The notation "*L* X-rays" is used only when *K* X-rays are absent or very weak. Similarly, conversion electrons are listed if they are prominent in the electron spectrum. Auger electrons (electrons emitted in the de-excitation of atomic levels) are not listed explicitly; they will always accompany the emission of X-rays. Continuous β^- or β^+ spectra are usually represented by the endpoint of the highest energy beta group followed by the notation "max." When the highest energy group is of low intensity, so that a spectrometer of low resolving power (such as a scintillator) would also detect the presence of a continuous spectrum with a lower endpoint energy, this is also indicated. Thus the notation "β^- 1.176 max (7%), 0.514 max" means that there is a continuous spectrum with endpoint 1.176 MeV and 7% intensity, but the major portion of the β^- spectrum (which may be composed of one *or more* beta groups) has an endpoint energy of 0.514 MeV. Decay products can often give rise to radiations that soon become prominent, and this is indicated by the notation "daughter radiations from . . ." so that the reader will look up the radiations that arise from these sources. The data in this column are derived from the references listed in Table II. *Quantities enclosed in square brackets are calculated or inferred, not measured.*

The term "major radiations," as used here, requires some explanation. In each of the three general categories of radiation, α particles, β particles and electrons, and γ rays and X-rays, we have listed the most prominent radiations, even though they may be of relatively low intensity. For example, with an α emitter may be listed a γ ray of only 10^{-5}% intensity relative to the α intensity if that γ ray is the most intense in its energy range. Conversion electrons are listed according to the actual energies of the electron lines and not in terms of the transitions that give rise to the lines.

The intensities of radiations when expressed as *percentages* without other qualifications refer to percentages of the total decay events. Another way of expressing *relative* intensities is also sometimes employed. A number following the dagger(†) symbol is the relative intensity for the particular mode of decay beside which the † appears.

The terms "doublet" and "complex" are used to indicate γ rays which would be unresolved or incompletely resolved by instruments of moderately low resolving power such as scintillators. It is *not* indicated when an electron line is complex. Because of conversion in different atomic shells and subshells, many of the electron lines listed in Column 5 are complex.

The reader is referred to Table II for a more detailed account of radiations accompanying the decay of each isotope and for references to the original literature.

Column 6—principal means of production. The methods for producing each isotope selected for inclusion here are those that have given the highest yield and those that permit greatest isotopic purity. These listings will serve principally as references to the original literature in which important aspects of the preparations such as experimental conditions, yields, and purity of product are discussed.

The methods fall into three main categories. For ordinary nuclear reactions in which a target isotope is bombarded with charged particles or neutrons the usual system of abbreviations is employed. For example, to make Pu^{237}, the reaction Np^{237} $(d, 2n)$ appears;

this means that Np^{237} is the target, deuterons (d) are the projectiles, and two neutrons ($2n$) are emitted. When the target material is not isotopically pure, the experimenter must be concerned with radioactive substances produced from other components of the target. A second category of production consists of the separation of the isotope in question from a radioactive parent. Such an isotope is indicated as the daughter of another. Finally, with the advent of very high fluxes of neutrons it has become possible to prepare isotopes by the successive capture of neutrons (with intervening β^- decay in some cases). Such preparations have been designated by "multiple n-capt from –," where the dash refers to the starting material.

TABLE II. DETAILED NUCLEAR LEVEL PROPERTIES

This section gives the type of information on nuclear states and transitions between these states familiar to nuclear spectroscopists. The tabulations are concerned with measurements; the diagrams are interpretations in the form of the familiar decay schemes and energy levels.

The general policy adopted for the entries made on the decay schemes is that they be based on direct experimental information. Spin and parity assignments based wholly, or in large part, on the expectations from nuclear models have been avoided. Unobserved transitions that should be present have been omitted. A few exceptions to these conventions will be found; for example, an obvious assignment of a state as a member of an otherwise well-characterized rotational band may be entered.

Similarly, information that can be *calculated* on the basis of a model has not been entered; for example, intensities of competing γ rays. Some useful numbers that do not depend on models do appear; for example, *log ft values* for β decay and *hindrance factors* for α decay. In some cases we have shown calculated values for electron capture branching or β^+ branching when only one has been measured. The calculated mode appears in square brackets. In general, brackets enclose information that may be inferred or calculated without recourse to detailed models.

The bulk of the information contained here (except for the lightest elements) comes from the study of radioactive decay processes. Increasingly, however, information is arriving from direct "in-beam" experiments involving inelastic and elastic scattering, Coulomb excitation, and nuclear reactions generally. The problem was how much of this information to include in the present compilation. Rather arbitrarily it was decided to include only those levels at energies below the decay energy of the observed neighboring isobars.

A. TABULATED DATA

Designation of state and its half-life. The isotopic designation appears at the heading for each entry with the total (measured) half-life for the ground state in parentheses. When separate entries are made for metastable (isomeric) states, it is the half-life of that state that is entered. Stable or long-lived naturally occurring isotopes are indicated by underlining, as in Table I.

Spins and moments. The line immediately below the designation of the isotope gives the spin and nuclear moments of the ground state. Most of these values are taken from the recent compilation by I. Lindgren (Lindgl64). A number of moments have been measured for excited states and are given where the particular state is listed. The spins and parities of excited states deduced from detailed examination of decay processes and similar other information will be found on the decay schemes and not among these tabulated data.

All magnetic dipole moments have been corrected for the diamagnetic effect. Unless otherwise stated, the spectroscopic electric quadrupole moments have not been corrected for polarization of the atomic electron shells (Sternheimer effect). The use of "±" with the magnetic dipole and electric quadrupole moments indicates that the signs are unknown.

The symbols used to designate spins and moments are the following:

I	Mechanical or spin moment in units of $\hbar$.
μ	Magnetic dipole moment in units of nuclear magnetons $$e\hbar/2M_pc$$ with the proton magnetic moment positive in sign.
q	Electric quadrupole moment in units of 10^{-24} cm^2 with usual convention of sign for prolate (+) and oblate (−) charge symmetry.
Ω	Magnetic octupole moment in units of nuclear magnetons × 10^{-24} cm^2.

Experimental methods are described as follows:

atomic spect	Hyperfine structure of optical spectra (includes both line and band spectra).
atomic beam	Atomic or molecular beam magnetic resonance (includes both the determination of hyperfine structure and the direct determination of moments by double resonance or other methods.
NMR	Nuclear magnetic resonance.
ESR	Electron spin resonance (includes electron-nuclear double resonance).
quad res	Quadrupole resonance.
microwave	Microwave absorption.
rotation $\gamma\gamma(\theta)$	Rotation of angular distribution pattern in a magnetic or electric field.

nucl alignment Static (low-temperature) nuclear orientation detected by anisotropy of the nuclear radiations.
nucl induction Dynamic (resonance) nuclear orientation detected by anisotropy of the nuclear radiations.
Mössbauer Mössbauer effect.
opt pump Optical pumping.
opt double res Optical double resonance.

Radiations emitted. The radiations are separated according to type: β^-, β^+, γ, α, p, n, SF. The emission of protons (p) and neutrons (n), and in a few cases α particles, occurs not from the parent substance but follows promptly a β-decay event. The relationship is shown on the decay scheme. The energies of the radiations are shown in boldfaced characters.

β groups. When there is more than one β group, they are numbered with subscripts so that corresponding entries from different authors may be compared directly. The intensities followed by the % symbol are absolute percentages of the total decay and should add to 100. In some instances in which branched decay occurs, or in which it is not certain that all of the β groups have been identified, intensities have been reported as relative values for the groups identified. Such entries are symbolized with a number preceded by a dagger (†). In cases of branched decay the fraction going by each mode will be found on the decay scheme and in Table I. The symbols used to describe the experimental methods for determining β energy and intensity are as follows:

mag spect Magnetic deflection (magnetic spectrometer or a counter employing a magnetic field).
scint spect Pulse-height analysis with a solid or liquid scintillation detector.
semicond spect Pulse-height analysis with a semiconductor detector.
ion ch Pulse-height analysis with an ionization chamber or proportional counter.
abs Absorption methods.
cl ch Cloud chamber with magnetic deflection.
$\beta\gamma$ coinc β- and γ-coincidence measurement with some form of spectrometer on one or both sides.

γ rays. When there is branched decay and it is known which γ rays accompany each mode, this is stated. The γ rays are often numbered for convenience in comparing entries from different authors. The energies (listed in boldfaced characters) pertain to transition energies, even though conversion electrons may have been measured. They are listed in ascending order of energy, irrespective of how they may fit into the decay scheme.

A concise system for indicating intensities of radiations involved in γ-ray transitions is difficult to arrive at because most experiments are not directed toward absolute determination. The reader is urged to give particular attention to the following description of the symbols employed:

The absolute scale of intensities adopted considers all primary decay events as 100%. An entry such as γ_3 **0.067** (γ 7%) means that the transition of 0.067 MeV, designated γ_3 has seven unconverted photons for each 100 decay events of the parent. The symbol γ preceding 7% emphasizes that it is the *photon* of transition γ_3 under consideration. The same form of symbolism may be used for conversion electrons, which for the K and L_I lines might read: γ_3 **0.067** (K 0.8%) and γ_3 **0.067** (L_I0.4%). When conversion coefficients are known, we have not used a separate symbol for photons and electrons but rather have symbolized the definition; for example, γ_3 **0.067** (γ 7%, e_K/γ 0.11); or γ_3 **0.067** (γ 7%, e_K/γ 0.11, K/L$_I$2) to show also a particular subshell conversion ratio.

The symbol † is used to signal that the numbers which follow in the same entry express relative intensities. (An entry begins with a line indented to the left and ends with a reference or references.) In many cases we have renormalized the intensity scale used in the original paper to give more convenient numbers or to facilitate comparison of different measurements. A series of γ rays may appear as follows: γ_1 **0.669** ($\dagger_\gamma$9), γ_2 **0.962** ($\dagger_\gamma$7), γ_3 **1.42** ($\dagger_\gamma$0.9). This means that the ratios of γ-ray (photon)intensities $\gamma_1/\gamma_2/\gamma_3$ have the values 9/7/0.9. If a conversion coefficient is known, it is generally entered in the parentheses in which the relative intensity of the γ ray appears.

Relative intensities of conversion electrons, if on the same scale as the γ rays, are also entered with the appropriate dagger sign; for example, $\dagger_K$. When γ rays and conversion electrons are not normalized to each other, a double dagger (‡) is used for one of them. For example, γ_3 ($\dagger_\gamma$7), γ_4 ($\dagger_\gamma$1), γ_5 ($\ddagger_K$10), γ_6 ($\ddagger_K$5) means that γ_3 is seven times as intense as γ_4 and $K(\gamma_5)$ is twice as intense as $K(\gamma_6)$ but implies no relation between the K-electron and γ-ray intensities.

With deference to compactness, the methods by which the γ-ray transition energies and intensities of radiations were determined have been grouped before the author reference or references. Those familiar with data and methods of nuclear spectroscopy will usually known how the indicated methods were employed. Certain coincidence methods used to establish sequences of events necessary for deriving the decay schemes are also called to the attention of the reader. Specific coincidence results are omitted from the data except when the coincidence relations implied are not shown on the decay scheme. The symbols employed have the following meanings:

mag spect conv Measurement of internal conversion electrons with a magnetic spectrometer or spectrograph.
mag spect Measurement of secondary (photo-, Compton) electrons as above.
scint spect Pulse-height analysis with a solid or liquid scintillation detector.

scint spect conv	Pulse-height analysis (conversion electron) with a solid or liquid scintillation detector.
sum scint spect	Measurement of scintillation spectrum at close geometry to emphasize sums of coincident γ rays.
3 cryst pair spect	Pulse-height analysis employing a 3-crystal pair spectrometer with scintillation detectors.
semicond spect	Pulse-height analysis with a semiconductor detector.
semicond spect conv	Pulse-height analysis (conversion electron) with a semiconductor detector.
$\gamma\gamma$ sum coinc	Measurement of the coincidence spectrum of two γ rays whose total energy is a fixed sum.
cryst spect	Measurement by diffraction with a bent crystal spectrometer.
coinc	Study involving coincidences or absence of coincidences ($\gamma\gamma$, $\beta\gamma$, γe^{-}, $\alpha\gamma$, etc.) with counters and, in some cases, spectrometers.
$\gamma\gamma^{\pm}$ coinc	Coincidence measurement between a γ-ray and annihilation radiation ($\gamma^{\pm}$). Comparable symbols are used for the measurement of other radiations in coincidence with annihilation photons.
coinc abs	Coincidence study using absorption techniques.
abs	Absorption of γ rays.
abs conv	Absorption of conversion electrons.
abs sec	Absorption of secondary electrons.
cl ch recoil	Observation of secondary electrons in a cloud chamber with magnetic field.
pair spect	Magnetic analysis of positron-electron pairs produced in a thin radiator by γ rays.
pair spect conv	Magnetic analysis of positron-electron pairs produced by internal pair conversion.
Be(γ, n), D(γ, n), D(γ, p)	Measurement of neutron or proton energies from these reactions.

A few rather specialized symbols are used occasionally with the γ-ray data: $e^{\pm}$ stands for pair conversion, $e_{K}{}^{+}$ for conversion by emission of a positron with simultaneous transfer of an electron into a vacant K orbit. $\dagger_{\gamma\gamma}/\dagger_{\gamma}$ is the ratio of two-quantum to single-quantum emission.

α particles. Energies of α groups are given in boldfaced characters, and in addition the group is designated by subscript according to the energy of the state (in kiloelectron volts) to which the α group leads, when known. For example, α_0 refers to the transition to the ground state and α_{51} to a state at 51 keV. All α energies are based on the Rytz standard, α_0 (Po^{210}) = 5.305 MeV (RytA61a, RytA61, RytA60). This involves an upward adjustment of about 0.11% for most values from the Berkeley laboratory, as well as for all other values quoted before about 1961. For pure α emitters intensities of the various groups are on an absolute scale and are designated by the % sign. Intensities of α groups, when there is branched decay, are designated with a † sign. In these cases the intensities are normalized to a total α-particle intensity of 100.

The methods for measuring energies and intensities are as follows:

mag spect	Magnetic deflection with photographic or counter detection.
semicond spect	Pulse-height analysis with a semiconductor detector.
ion ch	Pulse-height analysis with an ionization chamber or proportional counter.
$\alpha\gamma$ coinc	Coincidences between α particles and γ rays of selected energy. Usually α-particle energies measured with semiconductor counters (similar entries are made for coincidences with conversion electrons).
range emuls	Measurement of the length of an α-particle track in a photographic emulsion.

"Delayed" particles (p, n, α). In some cases these particles are emitted promptly from an excited state of a nucleus following β decay to that state. In certain light elements β decay leads to excited states in which α particles are unbound and are emitted promptly. Entries are made under the nucleus that emits the β particles. An exception is made in the case of "long range α-particles" from the excited levels of Po^{212} and Po^{214} following Bi^{212} and Bi^{214} .β^{-} decay. These α groups are listed with the α data of the respective polonium isotopes under the heading "long range α's."

The methods of measuring the "delayed" protons are similar to those used for α particles. For neutrons the following are employed:

p-recoil ion chamber	Determination of neutron energies by measurement of the energies of elastically scattered protons in an ionization chamber.
time of fl	Measurement of time-of-flight of neutrons in coincidence with β particles.
recoil scint spect	Measurement of scattered protons with a scintillation detector.

Energies quoted for all particle radiations are those of the emitted particles with no correction for the energy of the recoil nucleus.

Angular distributions. Following the listing of radiations for each isotope is a list of references to measurements of angular distributions between these radiations, denoted by the symbols $\beta\gamma$ (θ), $\alpha\gamma(\theta)$, $\gamma\gamma$ (θ) (includes gamma-gamma, gamma-conversion electron, and conversion-conversion correlations), and so on. References to polarization measurements, for example, $\gamma\gamma_{\text{polariz}}$ (θ), $\beta\gamma_{\text{polariz}}$ (θ), are also given.

Measured electron capture shell ratios and *electron capture/β^{+} ratios* are next listed for those nuclei that decay by electron capture (and positron emission).

The last listing for each isotope gives the *half-lives* and *moments* of excited states of that isotope. (When long-lived isomers of an isotope are listed as a separate entry half-lives and moments for short-lived levels are listed along with the data for the *ground state.*) The means by which excited level moments were determined are included in the discussion under *spins and moments*. Methods of determining half-lives are denoted as follows:

delay coinc Measurement of the time distribution interval between emissions of radiations which excite and de-excite a level.

nucl res fluor Determination of a γ-ray half-life from the resonant scattering cross section.

Coulomb excit Determination of a γ-ray half-life from Coulomb excitation cross section.

Doppler broadening Determination of the half-life of a γ ray emitted from a moving nucleus by measuring the broadening or shifting of the γ-ray line due to the Doppler effect.

nuclear recoil Determination of the half-life of a radiation emitted from a moving nucleus by measuring the distance the nucleus moves before emitting the radiation (includes electrostatic method for determining the distance the recoil nucleus traveled).

hf deflection Determination of the delay between two conversion electron transitions by accelerating one or both of the electrons in a high-frequency electric field and measuring the resulting energy shifts, detecting the two radiations in coincidence (see BlauA59, GerhT56a).

electron scattering Determination of a γ-ray half-life from the cross section for inelastic scattering of electrons (Coulomb excitation with electrons).

A few entries in Table II, which represent selection, normalization, and averaging of data from numerous papers on the same subject, have been designated "compiled from (references) . . . by LHP." As implied by the reference, we are responsible for any abuse of the original data.

B. DECAY SCHEMES

Note on references. It is not possible to place on each decay scheme references to all of the publications that contributed data. The few references entered are to those publications that either provided the decay scheme in the form shown or supplemented an established series of levels and transitions with some new ones. The reference NDS stands for Nuclear Data Sheets issued by Nuclear Data Group, Oak Ridge National Laboratory. No mention is made in the references that we have done some editing and piecing together of data in almost all of the decay schemes shown. In particular, information that the original authors considered uncertain has been eliminated to give clarity to the remainder.

Scope of information. Each figure pertains to the energy levels for a particular mass number. For β-decay processes all data fit into the scheme in a natural way because the mass number does not change. Energy levels populated by α decay will, of course, be connected with the α emitter which has a mass number four units higher. If the α emitter is also β unstable, the decay data pertinent to that mode will be found on the diagram for the appropriate mass number.

Energy levels excited by nuclear scattering, stripping, or nuclear reactions generally are not dealt with comprehensively in this compilation. In the first place, a rather arbitrary cut-off was made in confining our attention to states that lie at energies that could be reached by β decay of the isobars. The rationale (such as it is) lies in emphasizing radioactive decay data in this compilation but also in the presently valid generalization that high-lying states have not had the same type of theoretical scrutiny as the states closer to the ground state. (This generalization must be applied to a somewhat elastic energy scale which expands toward lighter elements.) An omission more important than the energy cut-off is an explanation of how these states were excited and de-excited and the relevance to the spins and/or parities assigned. In view of the rapid evolution of the means and methods for doing nuclear spectroscopy by means of nuclear reactions, the incorporation of such data into "decay schemes" is rapidly becoming mandatory if they are to serve the needs of nuclear spectroscopists.

Levels excited by nuclear reactions. The limitations in the entry of these levels have been mentioned in the preceding discussion. Such states may be found in the level diagrams by noting that we have omitted γ rays which de-excite these levels, even though it is often the γ transitions that establish the position and nature of the states. In the present format this obvious deficiency is compensated by the relatively greater ease of seeing the data on radioactivity that still predominate. The inset of references on each decay scheme contains those in which the full details of the population and interpretation of these levels will be found, and in many cases the groupings of certain states with their spins and parities will permit the knowledgeable reader to determine how the assignments were made without consulting the original work.

Ground states. Ground states are indicated by a heavy line immediately above the isotopic assignment (in large characters). A somewhat lighter line is used to indicate those isomeric states for which there is a separate entry in Tables I and II. Those ground states that are radioactive have their half-lives indicated near the line; the abbreviation for a unit of time makes unnecessary their placement in some standard position. An isotope that undergoes branched decay generally has the percent of branching shown for each mode, but other decay information is given only for the mode or modes pertinent to the mass number under consideration.

Energy levels in general. The horizontal lines that represent energy levels have the energies of excitation entered above them in boldfaced characters near the right-hand extremity. Energies are in units of million electron volts. The spins and parities are in similar characters and similarly placed on the left. We have not entered other descriptive quantum numbers even when they have been well established, but members of different rotational bands (for nuclei in the major regions of nuclear deformation) are slightly displaced horizontally. Assignments appearing within parentheses are consistent with available information but not determined uniquely. Sometimes when only two choices are possible both are entered. Uncertain levels and transitions are indicated by dashed lines.

Half-lives of excited states are entered at either end of the level or, in a few cases, on the level, in large characters. The abbreviations have the following meanings: ms = 10^{-3} sec, μs = 10^{-6} sec, ns = 10^{-9} sec, ps = 10^{-12} sec.

Beta-decay processes. Q values for β-decay modes are entered where convenient below the isotopic symbol. Those for β decay are designated Q_{β^-}, whereas for both positron decay and orbital electron capture they are given as Q_{EC}. The latter designation eliminates the ambiguity as to whether two electron masses have been added to the endpoint energy of the positron spectrum. Thus all Q values have their exact definition as the energy difference between the ground states of parent and daughter systems. Values given without other designation are based on decay data. Q values followed by the abbreviation *calc* were calculated from (a) masses established in a variety of ways, (b) closed decay cycles or decay-reaction cycles, or (c) ratios of electron capture from different shells for EC decay or EC/β^+ ratios. Those values followed by the symbol *est* were estimated from theoretical considerations of α or β systematics.

The intensities of β^-, β^+, and electron-capture groups indicated near the arrows showing the transitions are given as percentages of total transitions (%) or as relative intensities (†). To the right of the intensities are shown the log ft values (*italic* characters). Tie lines to the transition arrows are used for clarity. β branchings given are not necessarily directly measured. In fact, in a majority of cases they are inferred from γ-ray and conversion-electron data.

In some cases close-lying states are populated by β groups that cannot be resolved; the arrow then terminates at a bracket spanning these levels. An arrow that terminates away from all levels indicates that information is not available on the primary states populated.

Alpha decay. Q values represent the total α-decay energy which includes the recoil energy. The symbols *calc* and *est* have the same meaning as they have when applied to β decay.

The decay scheme for an α emitter of mass $A + 4$ is given along with the level diagram for mass A which includes the α daughter. The α-emitting parent is shown on this diagram as a line above its isotopic assignment (in smaller characters than those used for the mass A isotopes); α transitions are indicated by double-line arrows. The intensities are given as percentages of the total α-decay events. Adjacent to the intensity values are "hindrance factors" (*italic* characters). Because the meaning of this term may not be widely known, it is explained here. By means of a single normalizing lifetime the half-life for the *ground-state transition* of any *even-even α emitter* may be calculated rather accurately by using simple one-body α-decay theory. The hindrance factor for such a transition is defined as unity. Almost all other transitions have half-lives longer than those given by this calculation. The factor by which the actual half-life exceeds that calculated is termed the "hindrance factor." All hindrance factors given on the decay schemes were calculated by Helen Michel (MicH66) from the one-body spin-independent equations of Preston (PresM47); the reader is referred to these papers for details. They serve a function similar to that of the log ft value for β decay in that further demands are placed on the theory to explain the relative retardation from some adopted standard.

Gamma-ray transitions. Special note should be taken of the system employed for indicating intensities of γ-ray transitions (vertical lines). Because the array of energy levels will be populated differently by the different radioactive modes that feed them, it is cumbersome to give intensities on a single diagram which relate to decay events of each parent substance. The intensities shown (numbers printed diagonally in light characters) are relative values for the γ-ray (photon) de-excitation of the particular level above which they appear and sum to $\approx$100 for each level. Occasionally such numbers are calculated from conversion-electron intensities, which is then indicated by placing them in parentheses. Absolute photon intensities of some γ rays in nuclei that can be fed only by one radioactive parent are given to the left of the transition arrow with a % sign. Intensities of γ rays and conversion electrons expressed in other ways will be found in conjunction with the parent substance in the tabular data accompanying the decay schemes. Multipolarities of the transitions are entered on the vertical to the left of the transition arrow or above the arrow, following the energy.

The energies of the γ transitions are given in boldfaced characters beside the intensities or immediately above the arrows when no intensity data are listed. Energies of the first excited state to ground-state transition are omitted. An asterisk following the energy of a γ ray signifies that coincidence work (usually) has shown the existence of more than one γ ray of approximately the same energy. Consequently, the reader should search for other γ rays of that energy in the level diagram.

Table I

Radioisotope data

Half-life — type of decay — isotopic abundance — atomic mass — neutron cross-section (capture and fission) — class (assignment rating) — means of identification — genetic relationships — major radiations — means of production

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Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (△≡M−A), MeV (C^{12}≡0); Thermal neutron cross section (σ), barns		Class; Identification; Genetic relationships		Major radiations: approximate energies (MeV) and intensities		Principal means of production
$_0n^1$	11.7 m (SosA59, SosA58, SosA59a, ProkY62) 12.8 m (RobsJ51) 12 m (HameM56a) others (SneA50)	☢ Δ	β^- (ChadJ35, SneA50) 8.0714 (MTW)	A	recoil nuclei, conservation of momentum (ChadJ32) observation of (n, α) reaction (FeaN32, HarkW33) parent H^1 (SneA50, RobsJ50)	β^-	0.78 max	fission, $H^3(d,\alpha)$, $Be^9(\alpha,n)$, $H^2(d,He^3)$ $Be^9(\gamma,n)$ (photons from electron generator)
$\underline{_1H^1}$		% Δ σ_c	99.9852 (Lake Michigan water); 99.9842 to 99.9877 (other sources) (BegF59a) 99.9849 to 99.9861 (KirI51) 7.2890 (MTW) 0.332 (GoldmDT64)					
$\underline{H^2}$		% Δ σ_c	0.0148 (Lake Michigan water); 0.0123 to 0.0158 (other sources) (BegF59a) 0.0139 to 0.0151 (KirI51) 13.1359 (MTW) 0.0005 (GoldmDT64)					
H^3	12.262 y genet (JonWM55) 12.46 y genet (JenkG50) 12.5 y (PopM58) others (JonWM51, NoviA47, AlvL39, AlvL40, HugD48a, ONeaR40, CornR41)	☢ Δ σ_c	β^- (AlvL39, AlvL40) 14.9500 (MTW) $<6.7 \times 10^{-6}$ (GoldmDT64) (absorption not possible)	A	chem, sep isotopes, excit (AlvL39, AlvL40)	β^- γ	0.0186 max average β^- energy: 0.0057 calorimetric (PilW61) 0.0055 calorimetric (PopM58) others (GregD58) no γ	$Li^6(n,\alpha)$ (ONeaR40)
$\underline{_2He^3}$		% Δ σ	1.3×10^{-4} (atmosphere) 1.7×10^{-5} (wells) (AldL46, CoonJ49) 14.9313 (MTW) (n, p) 5330 (GoldmDT64)					$H^3(\beta^-)$
$\underline{He^4}$		% Δ σ_c	≈100 2.4248 (MTW) (total absorption) 0 (GoldmDT64)					
He^6	0.797 s (BieJ62) 0.799 s (KliR54) 0.85 s (BornG62, VeeN56) 0.83 s (HerrmW58, AlleJS59) 0.86 s (MalmS62) 0.82 s (HolmJ49) others (SomH46, RusB55, BattM53, VenG52, ShelR52a, PolA37, DewJ52)	☢ Δ	β^- (BjeT36b) 17.598 (MTW)	A	chem (BjeT36, BjeT36a) cross bomb, excit, chem (SomH46)	β^- γ	3.508 max no γ	$Be^9(n,\alpha)$ (RusB55, BjeT36, PolA37, SomH46, KnoW48, PerezV50) $Li^7(\gamma,p)$ (ShelR52a)
He^8	0.122 s (PosA65a) 0.03 s (NefB63a)	☢ Δ	β^- 100%, n 12% (PosA65a) 31.7 (CerJ66a)	B	chem, excit, cross bomb (PosA65)	β^- γ	[9.7 max] 0.98 (88%) daughter radiations from Li^8	protons on C, O (PosA65a)
$\underline{_3Li^6}$		% Δ σ	7.42 (OmuI58, HigM55, OrdK55) 7.29–7.42 (CamAE55) 14.088 (MTW) (n, α) 953 (GoldmDT64)					
$\underline{Li^7}$		% Δ σ_c	92.58 (OmuI58, HigM55, OrdK55) 92.58–92.71 (CamAE55) 14.907 (MTW) 0.037 (GoldmDT64)					

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_3$Li^8	0.841 s (KliR54) 0.83 s (RalW51) 0.88 s (BayD37, OglW47, ConnD59) 0.87 s (BretP53) 0.85 s (ShelR52a) others (HugD47a, WinnM54, BunbD53, NefB53a)	☢ β^-, 2α (LewisW37) Δ 20.946 (MTW)	A excit (CranH35a) n-capt, sep isotopes, genet (HugD47a)	β^- 13 max α 1.6 (broad peak, with 2.90 level of Be^8)	Li^7(n, γ) (ImhW59) Li^7(d, p) (CranH35a, DelL35, FowW37, BayD37, LewisW37, HornW50, YafL50)
Li^9	0.176 s (DosI65) 0.168 s (GardW51, ReaD53) 0.170 s (HoltR52) others (AlbuD63a, NefB63a, SchoR65, ShelR52a, BendP55)	☢ β^-, n, [2α] (GardW51, HoltR52) Δ 24.97 (MTW)	A excit, cross bomb (GardW51) genet energy levels (AlbuD63a)	β^- 13.61 max n 0.76 α [0.05 (with ground state of Be^8)]	Be^9(n, p) (AlbuD63a) Be^9(d, 2p) (GardW51, SchoR65)
$_4$Be^6	≈0.4 s (TyrH54)	☢ (TyrH54) Δ 18.37 (MTW)	G excit (TyrH54) nucleus is particle-unstable (AjzF59)		protons on Li, Be (TyrH54)
Be^7	53.6 d (KraJJ53a) 52.9 d (SegE49a) 53.1 d (EnglJ65) 53.0 d (RobeJ59, BouR56, BouR47) 53.5 d (WriH57)	☢ EC (RumL38) Δ 15.769 (MTW) σ (n, p) 54,000 (GoldmDT64)	A chem, cross bomb, excit (RumL38)	γ 0.477 (10.3%)	Li^6(d, n) (RumL38, RobeR38, ZloI42) B^{10}(p, α) (RobeR38, MaiH39) C^{12}(He^3, 2α) (EnglJ65)
Be^9		% 100 (NierA37a) Δ 11.351 (MTW) σ_c 0.009 (GoldmDT64)			
Be^{10}	2.5 x 10^6 y sp act + mass spect (MMilE47) 2.9 x 10^6 y yield (HugD47)	☢ β^- (MMilE46) Δ 12.607 (MTW)	A chem (MMilE46) chem, mass spect (PierAK46)	β^- 0.555 max γ no γ	Be^9(n, γ) (HugD47, AlbuD50, BellP50c) Be^9(d, p) (MMilE46, LeviJ47)
Be^{11}	13.6 s (WilkD59, NefB63a, AlbuD58c) 14.1 s (NurM58a)	☢ β^- (AlbuD58c, WilkD59) Δ 20.18 (MTW)	A excit, genet energy levels (AlbuD58c, WilkD59)	β^- 11.5 max γ 2.14 (32%), 4.67 (2.1%), 5.85 (2.4%), 6.79 (4.4%), 7.99 (1.7%)	B^{11}(n, p) (WilkD59, AlbuD58c)
Be^{12}	0.0114 s (PosA65)	☢ [β^-], n (PosA65) Δ 25 (PosA65, MTW)	C cross bomb (PosA65)		protons on O^{18}, N^{15}, F^{19}, Na^{23}, Al^{27}, O^{16} (PosA65)
$_5$B^8	0.77 s (MattE64) 0.78 s (DunnK58) others (ShelR52a)	☢ β^+, 2α (AlvL50) Δ 22.923 (MTW)	A excit, cross bomb (AlvL50)	β^+ [14.0 max] α 1.6 (broad peak, with 2.90 level of Be^8) γ [0.511 (200%, $\gamma^\pm$)]	Li^6(He^3, n) (DunnK58, MattE64)
B^{10}		% 19.6–19.8 (NewD59) 19.58 (ShiuV55) 18.45–18.98 (ThodH48) 19.3 (BentP58) 20.0 (LehW59) Δ 12.052 (MTW) σ (n, α) 3837 (GoldmDT64)			
B^{11}		% 80.2–80.4 (NewD59) 80.42 (ShiuV55) 80.0 (LehW59) 81.7 (BentP58) 81.02–81.55 (ThodH48) Δ 8.6677 (MTW) σ_c 0.005 (GoldmDT64)			
B^{12}	0.0203 s (FishT63, SchaA61) 0.0202 s (PeteRW63) 0.0189 s (KreW59) others (NorE56, BretP53, JelJ48a, BrolJ51, CookB56, CookB57)	☢ β^- (CranH35) β^- 100%, 3α 1.5% AlbuD63, CookCW57, CookCW58) Δ 13.370 (MTW)	A excit (CranH35, FowW36)	β^- 13.37 max γ 4.43 (1.3%) α 0.195 (1.5%), broad distribution to ≈3 MeV	B^{11}(d, p) (CranH35, FowW36, BrolJ51)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12} \equiv 0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_5B^{13}$	0.0186 s (MarqA62)	☢ β^- (MarqA62) no n, lim 0.3% (PosA65) Δ 16.562 (MTW)	B excit (HubbE53, NorE56) excit, genet energy levels (MarqA62)	β^- 13.44 max γ 3.68 (7%)	$B^{11}(t,p)$ (MarqA62)
$_6C^9$	0.127 s (HardJ65a)	☢ [β^+], p, [2α] (HardJ65a) Δ 29.0 (CerJ66)	B excit, cross bomb (HardJ65a)	p 8.2 (60%), 1.1 (40%), both peaks broad α [0.05, 1.6 (broad peak, with 2.90 level of Be^8)]	$B^{10}(p,2n)$ (HardJ65a) $B^{11}(p,3n)$ (HardJ65a)
C^{10}	19.48 s (EarL62) 19.3 s (BartiF63) 19.1 s (SherrR49)	☢ β^+ (SherrR49) Δ 15.66 (MTW)	A chem, sep isotopes (SherrR48, SherrR49)	β^+ 1.87 max γ 0.511 (200%, $\gamma^\pm$), 0.717 (100%), 1.023 (1.7%)	$B^{10}(p,n)$ (SherrR48, SherrR49)
C^{11}	20.34 m (KavT64) 20.4 m (FolK62, SmiJ41) 20.5 m (SolA41, PerlmM48, ChrisD50) 20.1 m (ArnS58) 20.3 m (MartiW52) others (KunD55, PoolM52, SiegK44a, DicksJ51, PatJ65)	☢ β^+ 99+%, EC(K) 0.19% (ScoJ57a) Δ 10.648 (MTW)	A excit (CranH34) chem, excit (BarkW39)	β^+ 0.97 max γ 0.511 (200%, $\gamma^\pm$)	$B^{11}(p,n)$ (BarkW39) $B^{10}(p,\gamma)$ (CranH34a, BarkW39) $B^{10}(d,n)$ (CocJ35, YosD35, FowW36) $N^{14}(p,\alpha)$ (BarkW39)
$\underline{C^{12}}$		% 98.892 (limestone CO_2) (NierA50) Δ ≡0 σ_c 0.0034 (GoldmDT64)			
$\underline{C^{13}}$		% 1.108 (limestone CO_2) (NierA50) Δ 3.125 (MTW) σ_c 0.0009 (GoldmDT64)			
C^{14}	5730 y (GodH62) 5745 y (HugE64, MannWB61) 5680 y (OlsI62) 5568 y (LibW55) (all values by sp act) others (WatD61, EngeA50, JonWM49, MillWW50, ManoG51, HawR49, ReidA46, HawR48, NorL48, YafL48a, CaswR54)	☢ β^- (KameM40) Δ 3.0198 (MTW)	A chem, cross bomb, excit (RubeS41)	β^- 0.156 max average β^- energy: 0.045 calorimetric (JenkG52) γ no γ	$N^{14}(n,p)$ (RubeS41, LibW55)
C^{15}	2.5 s (NeJB64) 2.25 s (DouR56) 2.4 s (HudE50a)	☢ β^- (HudE50) Δ 9.873 (MTW)	A excit, sep isotopes (HudE50) genet energy levels (WarbE65)	β^- 9.82 max (32%), 4.51 max (68%) γ 5.299 (68%)	$C^{14}(d,p)$ (HudE50, HudE50a, AlbuD59a)
C^{16}	0.74 s (HinS61a)	☢ [β^-], n (HinS61a) Δ 13.69 (MTW)	C excit, decay charac (HinS61a)		$C^{14}(t,p)$ (HinS61a)
$_7N^{12}$	0.01095 s (FishT63) 0.0110 s (PeteRW63) 0.0125 s (AlvL49a)	☢ β^+, 3α (AlvL50) β^+ 100%, 3α 3.0% (MayT62, GlasN63) Δ 17.36 (MTW)	A excit, sep isotopes (AlvL49a) genet energy levels (MayT62, WilkD63a, GlasN63, PeteRW63)	β^+ 16.4 max γ 0.511 (200%, $\gamma^\pm$), 4.43 (2.4%) α 0.195 (3%), broad distribution to ≈3 MeV	$C^{12}(p,n)$ (AlvL49a, AlvL50) $B^{10}(He^3,n)$ (PeteRW63)
N^{13}	9.96 m (EbrT65, ArnS58, DaniH58, DaniH57b) 10.05 m (FolK62, BormM65, ChurJ53) 10.08 m (WilkD55) 9.93 m (WardAG39a)	☢ β^+ (CranH34) Δ 5.345 (MTW)	A excit (CuriI34, CranH34)	β^+ 1.20 max γ 0.511 (200%, $\gamma^\pm$)	$B^{10}(\alpha,n)$ (CuriI34, ElliC35, RideL37a) $C^{12}(d,n)$ (CranH34, HafL35, YosD35, FowW36, CocJ35) $C^{13}(p,n)$ (AdaRE50) $C^{12}(p,\gamma)$ (HafL35, CocJ35)
$\underline{N^{14}}$		% 99.635 (NierA50) Δ 2.8637 (MTW) σ (n, p) 1.81 (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess $(\Delta \equiv M-A)$, MeV ($C^{12} \equiv 0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{7}N^{15}$		% 0.365 (NierA50) Δ 0.100 (MTW) σ_c 2.4×10^{-5} (GoldmDT64)			
N^{16}	7.14 s (BieJ64) 7.35 s (ElliJ59, BleE47) 7.16 s (GrayP65a) 7.31 s (MaimS62) 7.22 s (PinI62) others (MartiHC54, NelJB64, SomH46, CrePA65)	☢ β^- (LivM34a, FermE34) α 0.0006% (SegR61, SegR61b) α 0.0012% (KauW61) 0.0003% (AlbuD61) Δ 5.685 (MTW)	A excit (LivM34a, FermE34)	β^- 10.40 max (26%), 4.27 max γ 2.75 (1%), 6.13 (69%), 7.11 (5%) α 1.7	N^{15}(d, p) (AlbuD59a, FowW36) O^{16}(n, p) (ChanW37, BleE47) F^{19}(n, α) (LivM34a, FermE34, NahM36, PolA37) N^{15}(n, γ) (PinI62)
N^{17}	4.16 s (DosI65) 4.14 s (KnaK48) 4.15 s (StepW51)	☢ β^-, n (KnaK48) Δ 7.87 (MTW)	A chem, cross bomb (AlvL49, KnaK48, ChupW48)	β^- 8.68 max (1.6%), 7.81 max (2.6%), 4.1 max (95%) γ 0.87 (3%), 2.19 (0.5%) n 0.40 (45%), 1.21 (45%), 1.81 (5%)	N^{15}(t, p) (SilM64) C^{14}(α, p) (StepW51) O^{17}(n, p) (CharR49)
N^{18}	0.63 s (ChasL64)	☢ β^- (ChasL64) Δ 13.1 (ChasL64, MTW)	A sep isotopes, genet energy levels (ChasL64)	β^- 9.4 max γ 0.82 (59%), 1.65 (59%), 1.98 (100%), 2.47 (41%)	O^{18}(n, p) (ChasL64)
$_{8}O^{13}$	0.0087 s (MPheR65a)	☢ [β^+], p (MPheR65a) Δ 23.1 (CerJ66)	C excit, genet energy levels (MPheR65a, BartoR63)	p 6.40 (↑ 100), 6.97 (↑ 24)	N^{14}(p, 2n) (MPheR65a)
O^{14}	70.91 s (HendD61) 71.0 s (BardR62) 71.3 s (FrickG63) others (BardR60, GerhJ54, SherrR49, BromD57a, KuaH64a)	☢ β^+ (SherrR49) Δ 8.0080 (MTW)	A chem, excit (SherrR49) genet energy levels (SherrR53)	β^+ 4.12 max (0.6%), 1.811 max (99%) γ 0.511 (200%, $\gamma^{\pm}$), 2.312 (99%)	N^{14}(p, n) (SherrR49)
O^{15}	123 s (NelJW63) 124 s (PenJ57, KliR54, FolK62) 125 s (CsiJ63a) others (PerezV49, BashS55, KisO57, MMilE35a, BotW39, DuncD51, VasiSS63a)	☢ β^+ (LivM34) Δ 2.860 (MTW)	A chem, excit (LivM34, MMilE35a) excit (FowW36, KinL39a)	β^+ 1.74 max γ 0.511 (200%, $\gamma^{\pm}$)	N^{14}(d, n) (LivM34, MMilE35a, FowW36, BrowH50) N^{14}(p, γ) (DubL38, DuncD51) O^{16}(He^3, α) (WarbE65) C^{12}(α, n) (KinL39a, VasiSS63a)
O^{16}		% 99.759 (air O_2) (NierA50) O^{16}/O^{18} variation ≤4% (ThodH49, KameM46) Δ −4.7366 (MTW) σ_c 0.00018 (GoldmDT64)			
O^{17}		% 0.037 (air O_2) (NierA50) Δ −0.808 (MTW) σ (n, α) 0.24 (GoldmDT64)			
O^{18}		% 0.204 (air O_2) (NierA50) Δ −0.7824 (MTW) σ_c 0.00021 (GoldmDT64)			
O^{19}	29.1 s (MalmS62) 27.2 s (BormM65) 29.4 s (FulH44) 27.0 s (BleE47a)	☢ β^- (MarsJ43) Δ 3.333 (MTW)	A excit (NahM36) n-capt (MarsJ43)	β^- 4.60 max γ 0.197 (97%), 1.37 (59%)	O^{18}(n, γ) (MarsJ43, SerL47b, SerL46) O^{18}(d, p) (AlbuD59a)
O^{20}	14 s (SchaG60)	☢ [β^-] (SchaG60) Δ 3.80 (MTW)	B sep isotopes, excit, genet (SchaG60) parent F^{20} (SchaG60)	β^- [2.75 max] γ 1.06 (100%) daughter radiations from F^{20}	O^{18}(t, p) (SchaG60)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (△≡M−A), MeV (C¹² ≡ 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{9}F^{17}$	66.6 s (ArnS58) 66 s (KoesL54, WonC54a) others (WarrJ54, NewH35, PerezV50b, HorsR52, PerlmM48, DubL38, He tR58, VasiSS62c)	☢ β^+ (NewH35) △ 1.952 (MTW)	A cross bomb (WerI34, ElliC34a) chem, excit (NewH35, HaxO35, DubI38)	β^+ 1.74 max γ 0.511 (200%, $\gamma^\pm$)	$O^{16}(d, n)$ (NewH35, FowW36, PerezV50b) $N^{14}(\alpha, n)$ (WerL34, ElliC34a, RideL37a)
F^{18}	109.7 m (MahJ64) 109.9 m (EbrT63) others (BendW58, CarlC59, BegK63, HofmI64, BlasJ49, PerlmM48, KriR , JarN55, BormM , HubeO43, DubL , SneA37a)	☢ β^+ 97%, EC 3% (DreR56) △ 0.872 (MTW)	A chem (SneA37a) chem, sep isotopes, excit (DubL38)	β^+ 0.635 max γ O X-rays, 0.511 (194%, $\gamma^\pm$)	$O^{18}(p, n)$ (DubL38) $O^{16}(t, n)$ (MahJ64) $O^{16}(He^3, p)$ (MahJ64) $F^{19}(n, 2n)$ (BormM65) $F^{19}(d, t)$ (KriR41) $Ne^{20}(d, \alpha)$ (SneA37a)
F^{19}		% 100 (AstF20) △ −1.486 (MTW) σ_c 0.010 (GoldmDT64)			
F^{20}	11.56 s (MalmS62) 11.4 s (GliS63) 11.2 s (SchaG60) 10.7 s (SnoS50) others (CranH35a, VasiSS59)	☢ β^- (CranH35a) △ −0.012 (MTW)	A excit (CranH35, FowW36, NahM36) daughter O^{20} (SchaG60)	β^- 5.41 max γ 1.63 (100%)	$F^{19}(n, \gamma)$ (SerL47b, GliS63, NahM36) $F^{19}(d, p)$ (CranH35a, FowW36, SnoS50, JelJ50, NemY50)
F^{21}	4.35 s (ForJ65) 4.6 s (KieP63) 5 s (CamE52)	☢ β^- (KieP63) △ −0.05 (MTW)	A cross bomb (CamE52) genet energy levels (KieP63)	β^- 5.4 max γ 0.350 (? 100), 1.38 (? 13)	$O^{18}(\alpha, p)$ (ForJ65) $F^{19}(t, p)$ (KieP63, HorvP64, HinS62, SilM61a)
F^{22}	4.0 s (VauF65a)	☢ β^- (VauF65a) △ 4 (VauF65a, MTW)	B sep isotopes, genet energy levels (VauF65a)	β^- 11 max γ 1.28 (100%), 2.06 (67%)	$Ne^{22}(n, p)$ (VauF65a)
$_{10}Ne^{17}$	0.10 s (MPheR64)	☢ [β^+], p (MPheR64, BartoR63) △ 33.9 (MPheR64, MTW)	B excit, genet energy levels (MPheR64, BartoR63)	p 4.59	$F^{19}(p, 3n)$ (MPheR64)
Ne^{17}	0.69 s (DAurJ64)	☢ [β^+], p (DAurJ64)	G cross bomb (DAurJ64) activity not observed (EstR66)		
Ne^{18}	1.5 s (ButlJW61a, FrickG63) 1.6 s (GowJ54) others (EccD61)	☢ β^+ (GowJ54) △ 5.319 (MTW)	B excit, cross bomb (GowJ54)	β^+ 3.42 max γ 0.511 (200%, $\gamma^\pm$), 1.04 (7%)	$F^{19}(p, 2n)$ (GowJ54) $O^{16}(He^3, n)$ (FrickG63)
Ne^{19}	17.4 s (EarL62, AlleJS59) 17.7 s (PenJ57) 18.5 s (SchrG52) 18.6 s (BlasJ51b) 18.3 s (AlfWP57) 18.2 s (SherrR49) others (WhiM39, NahM54c, WallR60, VasiSS64)	☢ β^+ (WhiM39) △ 1.752 (MTW)	A cross bomb, excit (WhiM39)	β^+ 2.22 max γ 0.511 (200%, $\gamma^\pm$)	$F^{19}(p, n)$ (WhiM39, BlasJ51b, SchrG52)
Ne^{20}		% 90.92 (NierA50a) variations in Ne^{20}/Ne^{21} and Ne^{20}/Ne^{22} (WetG54) △ −7.042 (MTW)			
Ne^{21}		% 0.257 (NierA50a) △ −5.730 (MTW)			
Ne^{22}		% 8.82 (NierA50a) △ −8.025 (MTW) σ_c 0.04 (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}≡0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{10}$Ne^{23}	37.6 s (PenJ57) 37.5 s (AlleJS59, BurmRL59) 38.0 s (NurM58) 40.2 s (BrowH50a) others (HubeO44, RidlB58, AmaE35, BjeT37)	☢ β^- (PolE40) Δ −5.148 (MTW)	A excit (AmaE35) chem (BjeT37, PolA37)	β^- 4.38 max γ 0.439 (33%), 1.64 (0.9%)	Ne^{22}(n, γ) (LancH65) Ne^{22}(d, p) (PolE40, BrowH50a, PerezV50a) Na^{23}(n, p) (AmaE35, NahM36, PolA37, BjeT37, CarlT63)
Ne^{24}	3.38 m (DroB56)	☢ β^- (DroB56) Δ −5.95 (MTW)	B chem, genet (DroB56) ancestor Na^{24}, parent Na^{24m} (DroB56)	β^- 1.99 max γ 0.472 (100%, with Na^{24m}), 0.88 (8%) daughter radiations from Na^{24}	Ne^{22}(t, p) (DroB56)
$_{11}$Na^{20}	0.39 s (MacfR64a, BirgA52a) 0.23 s (ShelR51) 0.25 s (AlvL50)	☢ β^+, α (AlvL50, ShelR51) Δ 7.0 (PehR65b)	A excit (AlvL50) excit, cross bomb (MacfR64a) daughter Mg^{20} (MacfR64a)	β^+ [11.4 max] γ [0.511 (200%, $\gamma^\pm$), 1.63] α 2.14 (! 100), 2.49 (! 5), 4.44 (! 21)	Ne^{20}(p, n) (AlvL50) C^{12}(B^{10}, 2n), C^{12}(B^{11}, 3n) (MacfR64a)
Na^{21}	23.0 s (ArnS58) 21.6 s (WallR60) 22.8 s (SchrG52) 23 s (CreEC40c)	☢ β^+ (PolE40) Δ −2.19 (MTW)	A excit (CreEC40c)	β^+ 2.52 max γ 0.350 (2.3%), 0.511 (200%, $\gamma^\pm$)	Mg^{24}(p, α) (BradHu48) Ne^{20}(p, γ) (BrosK47) Ne^{20}(d, n) (PolE40)
Na^{22}	2.62 y (WyaE61) 2.58 y (MerW57) 2.60 y (LasL49) others (SahN59)	☢ β^+ 90.6%, EC 9.4% (WilliA64) β^+ 90%, EC 10% (KoniJ58c, SherrR54) β^+ 89%, EC 11% (AlleR55, KreW54a, HageH57) Δ −5.182 (MTW)	A chem, excit (FrisO35)	β^+ 1.820 max (0.05%), 0.545 max γ Ne X-rays, 0.511 (180%, $\gamma^\pm$), 1.275 (100%)	F^{19}(α, n) (FrisO35, LasL37, MagC37) Mg^{24}(d, α) (LasL37, AlbuD49)
$\underline{\mathrm{Na}^{23}}$		% 100 (SamM36a, WhiF56) Δ − 9.528 (MTW) σ_c 0.40 (to Na^{24m}) 0.53 (to Na^{24} by direct production + production via Na^{24m}) (GoldmDT64)			
Na^{24}	14.96 h (CamP58) 14.95 h (WolfG60) 15.05 h (WyaE61, JozE61, MonaJ62) 14.97 h (LocE53) 15.06 h (SreJ51) 15.10 h (CobJ50) 15.04 h (SolA50) 14.90 h (TobJ55) others (PouA59, LovG60, SinW51, WilsR49, ForS52, WriH57)	☢ β^- (LawE35) Δ −8.418 (MTW)	A chem, excit (FermE34, LawE35) descendant Ne^{24} (DroB56)	β^- 4.17 max (0.003%), 1.389 max (100%) γ 1.369 (100%), 2.754 (100%)	Na^{23}(n, γ) (AmaE35, SerL47b)
Na^{24m}	0.0203 s (AlexKF63) 0.0199 s (SchaA61) others (GlagV61, AlexKF60, CamE59, GlagV59, DroB56)	☢ IT, β^- (DroB56) Δ −7.945 (LHP, MTW)	A genet (DroB56) n-capt (FetP62a) daughter Ne^{24} (DroB56)	β^- 6 max γ 0.472	daughter Ne^{24} (DroB56) Na^{23}(n, γ) (CamE59, AlexKF60) Na^{23}(d, p) (SchaA61)
Na^{25}	60 s (RieW44, IweJ55, NahM56) 61 s (HubeO44) 62 s (PerlmM48, BaldG46) 58 s (BleE47a)	☢ β^- (HubeO43b) Δ −9.36 (MTW)	A excit (HubeO43b) genet energy levels (MaeD55)	β^- 3.83 max γ 0.39 (14%), 0.58 (14%), 0.98 (15%), 1.61 (6%)	Mg^{25}(n, p) (HubeO43b, BleE47a)
Na^{26}	1.04 s (NurM58) 1.03 s (RobiE61)	☢ β^- (NurM58) Δ −7.7 (MTW)	B excit (NurM58) genet energy levels (RobiE61)	β^- 6.7 max γ 1.82 (100%)	Mg^{26}(n, p) (NurM58, RobiE61)
$_{12}$Mg^{20}	0.6 s (MacfR64a)	☢ [β^+] (MacfR64a) Δ 16 (MacfR64a, PehR65b)	C genet (MacfR64a) parent Na^{20} (MacfR64a)		Ne^{20} on Al^{27} (MacfR64a)
Mg^{21}	0.121 s (MPheR65)	☢ [β^+], p (MPheR65, BartoR63) Δ 10.9 (MPheR65, MTW)	C excit, cross bomb (MPheR65, BartoR63)	p 3.3, 3.8, 4.58, 6.14	Na^{23}(p, 3n) (MPheR65)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{12}Mg^{22}$ (or Al^{23})	0.13 s (TyrH54)	☢ Δ −0.38 (CerJ66a)	F excit (TyrH54)		protons on Mg (TyrH54)
Mg^{23}	12.1 s (MihM58) 11.9 s (WallR60, HubeO43) 12.3 s (BolF51) 11.6 s (WhiM39) 11 s (HunS54)	☢ β^+ (WhiM39) Δ −5.472 (MTW)	A excit, cross bomb (WhiM39)	β^+ 3.03 max γ 0.44 (9%), 0.511 (200%, $\gamma^\pm$)	$Na^{23}(p, n)$ (WhiM39, DubL40a)
Mg^{24}		% 78.60 (WhiJ48) 78.8 (WhiF56) Δ −13.933 (MTW) σ (total absorption) 0.03 (GoldmDT64)			
Mg^{25}		% 10.11 (WhiJ48) 10.2 (WhiF56) Δ −13.191 (MTW) σ (total absorption) 0.3 (GoldmDT64)			
Mg^{26}		% 11.29 (WhiJ48) 11.1 (WhiF56) Δ −16.214 (MTW) σ_c 0.027 (GoldmDT64)			
Mg^{27}	9.46 m (PouA59) 9.51 m (DaniH53) 9.45 m (SargB53) 9.39 m (LocE53) 9.5 m (ElliJ59, BonaG64) 9.6 m (EklS43, ForS52, SalS65) others (CriE39, HendM35)	☢ β^- (HendM35) Δ −14.583 (MTW) σ_c <0.030 (GoldmDT64)	A chem, excit (AmaE35, HendM35)	β^- 1.75 max γ 0.18 (0.7%), 0.84 (70%), 1.013 (30%)	$Mg^{26}(n, \gamma)$ (AmaE35, SerL47b)
Mg^{28}	21.2 h (LindnM53) 21.3 h (ShelR53) 21.8 h (IweJ53) 22.1 h (JonJW53) 20.8 h (MarqL53) 21.4 h (WapA53c)	☢ β^- (LindnM53, ShelR53) Δ −15.02 (MTW)	A chem, genet (LindnM53, ShelR53) parent Al^{28} (LindnM53, ShelR53)	β^- 0.46 max e^- 0.030 γ 0.031 (96%), 0.40 (30%), 0.95 (30%), 1.35 (70%) daughter radiations from Al^{28}	$Mg^{26}(t, p)$ (IweJ53, MidR64b) $Mg^{26}(\alpha, 2p)$ (WapA53c, ShelR53, ShelR54)
$_{13}Al^{23}$ (or Mg^{22})	0.13 s (TyrH54)	☢ Δ −0.38 (CerJ66a)	F excit (TyrH54)		protons on Mg (TyrH54)
Al^{24}	2.10 s (GlasN53) 2.0 s (BrecS54) 2.5 s (BirgA52)	☢ β^+ 100%, α ≈10^{-2}% (GlasN55) Δ − 0.1 (MTW)	A excit, decay charac (BirgA52)	β^+ 8.5 max γ 0.511 (200%, $\gamma^\pm$), 1.368, 2.754, 4.2, 5.3, 7.1 α 2	$Mg^{24}(p, n)$ (BirgA52, BrecS54, GlasN53)
Al^{25}	7.24 s (MullT58a) 7.1 s (ArnS58) 7.3 s (WallR60, BradHu48) 7.6 s (HunS54a, ChurJ53)	☢ β^+ (BradHu48) Δ −8.93 (MTW)	B excit, sep isotopes (BradHu48)	β^+ 3.24 max γ 0.511 (200%, $\gamma^\pm$)	$Mg^{24}(p, \gamma)$ (HunS54a, ArnS58, MullT58a) $Mg^{25}(p, n)$ (BradHu48)
Al^{26}	7.4 x 10^5 y sp act + mass spect (RigR58) 8 x 10^5 y sp act + mass spect (FishP58) others (RigR57)	☢ β^+ 85%, EC 15% (RigR59) Δ −12.211 (MTW)	A chem, decay charac (SimaJ54) chem, cross bomb, mass spect (RigR58)	β^+ 1.17 max γ Mg X-rays, 0.511 (170%, $\gamma^\pm$), 1.12 (4%), 1.81 (100%)	$Mg^{26}(p, n)$ (HandT55a) $Mg^{25}(d, n)$ (RigR59, FergJ58) $Si^{28}(d, \alpha)$ (LauM55)
Al^{26m}	6.37 s (FreeJ65, FreeJ62a) 6.28 s (MullT58a) 6.74 s (MihM58) 6.5 s (KatzL51a, HasR54, ArnS58) 6.7 s (HunS54a, ChurJ53) others (FrickG63, WhiM39, AllaH48, PerlmM48, WafH48)	☢ β^+ (FrisO34) Δ −11.982 (LHP, MTW)	A excit (FrisO34) cross bomb (HubeO43, BradHu48)	β^+ 3.21 max γ 0.511 (200%, $\gamma^\pm$)	$Na^{23}(\alpha, n)$ (FrisO34, MagC37)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12} ≡ 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{13}Al^{27}$		% 100 (BaiK50, WhiF56) Δ −17.196 (MTW) σ_c 0.235 (GoldmDT64)			
Al^{28}	2.31 m (ElliJ59, MalmS62) 2.27 m (BarthR53b) 2.30 m (EklS43) others (CohAV56, SzaA48, IweJ53, FlorJ62)	☢ β^- (MMilE35) Δ −16.855 (MTW)	A chem, excit (CuriI34b, CuriI34a, FermE34) chem, cross bomb (AmaE35) daughter Mg^{28} (LindnM53, ShelR53)	β^- 2.85 max γ 1.780 (100%)	Al^{27}(n, γ) (AmaE35, SerL47b, OrsA49, HumV51, MotH52a) daughter Mg^{28} (LindnM53, ShelR53)
Al^{29}	6.6 m (SeiL49) 6.7 m (BetH39) 6.4 m (HendW39) others (MeyA37, IweJ53)	☢ β^- (BetH39) Δ −18.22 (MTW)	A excit, cross bomb (BetH39)	β^- 2.40 max γ 1.28 (94%), 2.43 (6%)	Mg^{26}(α, p) (ElliC36, BetH39, HendW39, SeiL49)
Al^{30}	3.3 s (RobiE61b) 3 s (PeeE63)	☢ β^- (RobiE61b) Δ −17.2 (MTW)	C excit, genet energy levels (RobiE61b)	β^- 5.0 max γ [1.27 (46%)], 2.23 (61%), 3.51 (39%)	Si^{30}(n, p) (RobiE61b, PeeE63)
Al^{30}	72 s (PeeE63)	☢ IT (?) (PeeE63)	C chem, sep isotopes (PeeE63)	γ 2.23, 3.51	Si^{30}(n, p) (PeeE63)
$_{14}Si^{25}$	0.23 s (MPheR65)	☢ [β^+], p (BartoR63, MPheR56) Δ 4.0 (MPheR65, MTW)	C excit, cross bomb (BartoR63, MPheR65)	p 3.34, 4.08, 4.68, 5.39	Al^{27}(p, 3n) (MPheR65)
Si^{26}	2.1 s (FrickG63, RobiE60) 1.7 s (TyrH54)	☢ β^+ (RobiE60, FrickG63) Δ −7.13 (MTW)	C excit (RobiE60)	β^+ 3.83 max γ 0.511 (200%, $\gamma^{\pm}$), 0.82 (34%) daughter radiations from Al^{26m}	Mg^{24}(He^3, n) (RobiE60, FrickG63)
Si^{27}	4.14 s (MihM58, KusI57) 4.22 s (BubI65) 4.45 s (SumR53) 4.1 s (WallR60, HunS54, VasiSJ60a) others (ElliD41a, WafH48, BolF51)	☢ β^+ (MCreR40) Δ −12.386 (MTW)	A excit (KueG39)	β^+ 3.85 max γ 0.511 (200%, $\gamma^{\pm}$)	Al^{27}(p, n) (KueG39, MCreR40, BarkW40a, CassJ51)
Si^{28}		% 92.18 (ReynJH53) 92.27 (BaiK50) Δ −21.490 (MTW) σ (total absorption) 0.08 (GoldmDT64)			
Si^{29}		% 4.71 (ReynJH53) 4.68 (BaiK50) Δ −21.894 (MTW) σ (total absorption) 0.3 (GoldmDT64)			
Si^{30}		% 3.12 (ReynJH53) 3.05 (BaiK50) Δ −24.439 (MTW) σ_c 0.11 (GoldmDT64)			
Si^{31}	2.62 h (CicJ38, WenA51, DVriL52) 2.65 h (MotH52) 2.59 h (LusE50) others (NewH37, AlleW40, ForS52)	☢ β^- (NewH35a) Δ −22.96 (MTW)	A n-capt (AmaE35) chem, excit (NewH35a)	β^- 1.48 max γ 1.26 (0.07%)	Si^{30}(n, γ) (AmaE35, SerL47b)
Si^{32}	≈650 y yield (GeiD62) ≈710 y yield (LindnM53) others (TurA53, RoyL57)	☢ β^- (LindnM53) Δ −24.08 (BrodR64, MTW)	A chem, genet (LindnM53, TurA54, BrodR64) parent P^{32} (LindnM53, TurA54, BrodR64)	β^- 0.21 max γ no γ daughter radiations from P^{32}	Si^{30}(t, p) (GeiD62) protons on Cl (LindnM53, BrodR64)
$_{15}P^{28}$	0.28 s (GlasN55) 0.29 s (BrecS54) 0.27 s (TyrH54)	☢ β^+, no α (GlasN55, GlasN53, BrecS54) Δ −7.7 (MTW)	B excit, decay charac (GlasN53, BrecS54)	β^+ 11.0 max γ 0.511 (200%, $\gamma^{\pm}$), 1.780 (75%), 2.6, 4.44 (10%), 4.9, 6.1, 6.7, 7.0, 7.6 (5%)	Si^{28}(p, n) (GlasN55, BrecS54, TyrH54)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{15}P^{29}$	4.45 s (RoderH55, RoderH53) 4.2 s (WallR60) 4.6s (WhiM41)	☢ β^+ (WhiM41) Δ −16.95 (MTW)	A excit (WhiM41) genet energy levels (RoderH55)	β^+ 3.95 max γ 0.511 (200%, $\gamma^\pm$), 1.28 (0.8%), 2.43 (0.2%)	Si^{28}(d, n) (RoderH55)
P^{30}	2.50 m (MDonW63) 2.49 m (EbrT65) 2.51 m (ArnS58) 2.55 m (KoesL54) others (RideL37a, VasiSS62c, FrickG63, BaskK52, CicJ38)	☢ β^+ (CuriI34) Δ −20.20 (MTW)	A excit (CuriI34, FrisO34)	β^+ 3.24 max γ 0.511 (200%, $\gamma^\pm$), 2.23 (0.5%)	Al^{27}(α, n) (FrisO34, CuriI34, RideL37a) S^{32}(d, α) (VasiSS62c, SagR36) Si^{29}(p, γ) (BotW39, BaldG46, PerlmM48)
P^{31}		% 100 (AstF20, KerL54) Δ −24.438 (MTW) σ_c 0.19 (GoldmDT64)			
P^{32}	14.28 d (MaraP61) 14.22 d (AndeO57) 14.30 d (CacB38, BayJ50) 14.58 d (RobeJ59) 14.60 d (SinW51) 14.50 d (LocE53) 14.35 d (KlemE48) others (MuldD40)	☢ β^- (LymE37) Δ −24.303 (MTW)	A chem, n-capt (AmaE35) daughter Si^{32} (LindnM53, TurA54, BrodR64)	β^- 1.710 max average β^- energy: 0.69 calorimetric (ShimN56a, HovV62) 0.70 ion ch (CaswR52, BrabJ53)	P^{31}(n, γ) (SerL47b) S^{34}(d, α) (SagR36) S^{32}(n, p) (AmaE35)
P^{33}	24.4 d (NicR54) 25.2 d (FogI60) 24.8 d (JensE52) 25 d (WestT52, ShelR51a)	☢ β^- (JensE52, ShelR51a) Δ −26.335 (MTW)	A chem, cross bomb (ShelR51a)	β^- 0.248 max γ no γ	S^{33}(n, p) (ShelR51a, JensE52, WestT52, NicR54, FogI60) Cl^{37}(γ, α) (ShelR51a)
P^{34}	12.4 s (BleE46) 12.7 s (CorkJ40a) 12.5 s (ScaR58)	☢ β^- (ZunW45) Δ −24.8 (MTW)	B excit (CorkJ40a) chem, excit, cross bomb (BleE46)	β^- 5.1 max γ 2.13 (25%), 4.0 (0.2%)	Cl^{37}(n, α) (ZunW45, HubeO45, BleE46, ScaR58) S^{34}(n, p) (CorkJ40a, ZunW45, BleE46)
$_{16}S^{29}$	0.19 s (HardJ64)	☢ [β^+], p (HardJ64) Δ −2.9 (HardJ64, MTW)	C excit, cross bomb (HardJ64)	p 3.73, 5.40	P^{31}(p, 3n) (HardJ64)
S^{30}	1.4 s (FrickG63, RobiE61a)	☢ β^+ (RobiE61a) Δ −14.09 (MTW)	C excit, genet energy levels (RobiE61a)	β^+ 5.09 max (20%), 4.42 max (80%) γ 0.511 (200%, $\gamma^\pm$), 0.687 (80%) daughter radiations from P^{30}	Si^{28}(He^3, n) (RobiE61a, FrickG63)
S^{31}	2.72 s (MihM58) 2.66 s (HasR52) 2.61 s (LindeKH60) 2.6 s (WallR60, NelJW63, MElhJ49) 2.4 s (HunS54) others (ElliD41a, WhiM41, BolF51, VasiSS63)	☢ β^+ (WhiM41) Δ −18.99 (MTW)	A excit, cross bomb (WhiM41, ElliD41a)	β^+ 4.42 max γ 0.511 (200%, $\gamma^\pm$), 1.27 (1.1%)	P^{31}(p, n) (WhiM41) Si^{28}(α, n) (ElliD41, ElliD41a, KinL40)
S^{32}		% 95.0 (BradP56) 95.018 (meteoritic sulfur) (MacnJ50a) terrestrial S^{32}/S^{34} variation ≤5% (TudA50) S^{32}/S^{34} variation (KulJ56) Δ −26.013 (MTW)			
S^{33}		% 0.760 (BradP56) 0.750 (meteoritic sulfur) (MacnJ50a) Δ −26.583 (MTW)			
S^{34}		% 4.22 (BradP56) 4.215 (meteoritic sulfur) (MacnJ50a) Δ −29.934 (MTW) σ_c 0.27 (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{16}S^{35}$	87.9 d (FlyK65a) 86.4 d (CoopR59) 87.2 d (SelH58) 89 d (WyaE61, CaliJ59) 87 d (HendR43) 88 d (LeviH40, KameM41) others (SerL47b, CoolR39, MauW49, RudG52)	☢ β^- (LibW39) Δ −28.847 (MTW)	A chem, excit (AndeEB36a) chem, cross bomb, excit (KameM41) sep isotopes (KameM42)	β^- 0.167 max average β^- energy: 0.0488 calorimetric (ConnR57, HovV64) γ no γ	$S^{34}(n, \gamma)$ (SerL47b) $Cl^{37}(d, \alpha)$ (KameM41)
S^{36}		% 0.014 (BradP56) 0.017 (meteoritic sulfur) (MacnJ50a) Δ −30.66 (MTW) σ_c 0.14 (GoldmDT64)			
S^{37}	5.07 m (ElliJ59) 5.04 m (BleE46) others (ScaR58)	☢ β^- (ZunW45) Δ −27.0 (MTW)	B chem, excit, cross bomb (ZunW45, BleE46)	β^- 4.7 max (10%), 1.6 max (90%) γ 3.09 (90%)	$S^{36}(n, \gamma)$ $Cl^{37}(n, p)$ (BleE46, ZunW45, ScaR58)
S^{38}	2.87 h (NetD58)	☢ β^- (NetD58) Δ −26.8 (MTW)	B chem, genet (NetD58) parent Cl^{38}, not parent Cl^{38m} (NetD58)	β^- 3.0 max (5%), 1.1 max γ 1.88 (95%) daughter radiations from Cl^{38}	$Cl^{37}(\alpha, 3p)$ (NetD58)
$_{17}Cl^{32}$	0.306 s (GlasN53) 0.32 s (BrecS54) 0.28 s (TyrH54) others (LeiO56)	☢ β^+, $\alpha \approx 0.01\%$ (GlasN53) Δ −12.8 (MTW)	B excit, genet energy levels (GlasN53, GlasN55, TyrH54)	β^+ 9.9 max γ 0.511 (200%, $\gamma^{\pm}$), 2.24 (70%), 4.29 (7%), 4.77 (14%)	$S^{32}(p, n)$ (GlasN53)
Cl^{33}	2.53 s (MullT58a) 2.9 s (WallR60) 2.4 s (WhiM41) 2.8 s (HoaJ40, SchelA48) others (VasiSS62c, BolF51, TyrH54)	☢ β^+ (WhiM41) Δ −21.01 (MTW)	A excit (HoaJ40, WhiM41)	β^+ 4.55 max γ 0.511 (200%, $\gamma^{\pm}$), 2.9 (0.3%)	$S^{32}(d, n)$ (HoaJ40, SchelA48) $S^{33}(p, n)$ (WhiM41)
Cl^{34}	1.56 s (FreeJ65, JaneJ61) 1.61 s (MihM58) 1.53 s (KliR54) others (StahP53, ArbW53a, ScaR58)	☢ β^+ (StahP53a, ArbW53) Δ −24.45 (MTW)	A genet (ArbW53, StahP53a) excit (FreeJ65) daughter Cl^{34m} (ArbW53a)	β^+ 4.46 max γ 0.511 (200%, $\gamma^{\pm}$)	daughter Cl^{34m} (ArbW53a) $P^{31}(\alpha, n)$ (JaneJ61)
Cl^{34m}	31.99 m (EbrT65) 32.40 m (GreeD56) 32.5 m (HinN52a) 33.2 m (WafH48) 33.0 m (PerlmM48) others (ScaR58, TohT60, SagR36, BranH38)	☢ $\beta^+ \approx 50\%$, IT $\approx 50\%$ (ArbW53, StahP53a) Δ −24.31 (LHP, MTW)	A chem, excit (FrisO34, SagR36) parent Cl^{34} (ArbW53a)	β^+ 2.48 max e^- 0.142 γ Cl X-rays, 0.145 (45%), 0.511 (100%, $\gamma^{\pm}$), 1.17 (12%), 2.12 (38%), 3.30 (12%) daughter radiations from Cl^{34}	$P^{31}(\alpha, n)$ (FrisO34, RideL37a, BranH38)
Cl^{35}		% 75.53 (BoydA55) 75.79 (ShieW62) 75.4 (NierA36) Cl^{35}/Cl^{37} variation <0.2% (OweH55) Δ −29.015 (MTW) σ_c 44 (GoldmDT64)			
Cl^{36}	3.08×10^5 y sp act + mass spect (BarthR55) 2.6×10^5 y sp act, yield (WriH57) 4.4×10^5 y sp act (WuC49) others (SerL47b)	☢ β^- 98.1%, EC 1.9%, β^+ 0.0012% (DreR55, DouP62a) β^+ 0.002% (BereD62a) Δ −29.520 (MTW) σ_c 100 (GoldmDT64)	A chem, n-capt (GrahD41)	β^- 0.714 max γ S X-rays, 0.511 (0.003%, $\gamma^{\pm}$)	$Cl^{35}(n, \gamma)$ (GrahD41, SerL47b)
Cl^{37}		% 24.47 (BoydA55) 24.6 (NierA36) 24.20 (ShieW62) Cl^{35}/Cl^{37} variation <0.2% (OweH55) Δ −31.765 (MTW) σ_c 0.4 (to Cl^{38}) 0.005 (to Cl^{38m}) (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
${}_{17}Cl^{38}$	37.2 m (CobJ50) 37.1 (MonaJ62) others (VVooS36, HoleN46, HurD37, MacqP55, CurrS40a, SlaH45, MacqP54a)	☢ β^- (KuriF36) Δ −29.80 (MTW)	A chem, n-capt (AmaE35) chem, sep isotopes (KenJ40) daughter S^{38} (NetD58)	β^- 4.91 max γ 1.60 (38%), 2.170 (47%)	$Cl^{37}(n, \gamma)$ (AmaE35, KenJ40, SerL47b, AkaH41)
Cl^{38m}	0.74 s (KieP62b) 1.0 s (SchaG54)	☢ IT (KieP62b) Δ −29.13 (LHP, MTW)	C n-capt, sep isotopes (SchaG54)	γ 0.66 (100%) e^- 0.66	$Cl^{37}(n, \gamma)$ (KieP62b, SchaG54)
Cl^{39}	55.5 m (HasR49) others (RudG52, MillDR48a)	☢ β^- (HasR49) Δ −29.80 (MTW)	A chem (MillDR48a) chem, excit (HasR4)	β^- 3.45 max (7%), 2.18 max (8%), 1.91 max γ 0.246 (44%), 1.27 (50%), 1.52 (42%)	$Ar^{40}(\alpha, \alpha p)$ (PenJ56) $Ar^{40}(\gamma, p)$ (HasR49, HasR50)
Cl^{40}	1.4 m (MoriH56)	☢ β^- (MoriH56) Δ −27.5 (MTW)	B chem, genet energy levels (MoriH56)	β^- 7.5 max γ 1.46 (? 100), 2.83 (? 100), 3.10, 5.8	$Ar^{40}(n, p)$ (GrayP65, MoriH56)
${}_{18}Ar^{33}$	0.18 s (ReeP64, HardJ65)	☢ $[\beta^+]$, p (ReeP64, HardJ65) Δ −9.5 (ReeP64, MTW)	C excit, decay charac (ReeP64)	p 3.16	$Cl^{35}(p, 3n)$ (HardJ65) $S^{32}(He^3, 2n)$ (ReeP64)
Ar^{35}	1.83 s (KisO56, AlleJS59) 1.76 s (NelJW63) 1.88 s (ElliD41) 1.84 s (SchelA48) 1.8 s (WallR60)	☢ β^+ (ElliD41, WhiM41) Δ −23.05 (MTW)	A excit (WhiM41, KinL40)	β^+ 4.94 max γ 0.511 (200%, $\gamma^\pm$), 1.22 (5%), 1.76 (2%)	$S^{32}(\alpha, n)$ (KinL40, SchelA48) $Cl^{35}(p, n)$ (WhiM41)
Ar^{36}		% 0.337 (NierA50) Ar^{36}/Ar^{38} variations (WetG54, FleW53) Δ −30.232 (MTW) σ_c 6 (GoldmDT64)			
Ar^{37}	35.1 d (StoeR65) 34.3 d (KisR59) 35.0 d (MiskJ52, PerlmM53) 34.1 d (WeimP44) 32 d (AndeC53)	☢ EC (WeimP44, RodebG52) Δ −30.951 (MTW)	A chem, cross bomb (WeimP41)	γ Cl X-rays, continuous bremsstrahlung to 0.81 (weak)	$Cl^{37}(p, n)$, $Cl^{37}(d, 2n)$, $S^{34}(\alpha, n)$, $K^{39}(d, \alpha)$, $Cl^{37}(d, 2n)$, $Ca^{40}(n, \alpha)$ (WeimP44, WeimP41) $Ar^{36}(n, \gamma)$
Ar^{38}		% 0.063 (NierA50) Ar^{36}/Ar^{38} variations (WetG54, FleW53) Δ −34.718 (MTW) σ_c 0.8 (GoldmDT64)			
Ar^{39}	269 y sp act (StoeR65) ≈265 y sp act (ZelH52)	☢ β^- (BrosA50) Δ −33.24 (MTW)	B chem, excit (ZelH52)	β^- 0.565 max γ no γ	neutrons on KCl (ZelH52) $Ar^{38}(n, \gamma)$ (KatcS52)
Ar^{40}		% 99.600 (NierA50) Δ −35.038 (MTW) σ_c 0.61 (GoldmDT64)			
Ar^{41}	1.83 h (H[illegible]gW51, PauH64, KatcS52, SneA36) 1.82 h (BleE46b) 1.85 h (SchwaA56)	☢ β^- (SneA36) Δ −33.061 (PauH64, MarlK65, MTW) σ_c 0.5 (StoeR65)	A chem, excit (SneA36) mass spect (AndeG54)	β^- 2.49 max (0.8%), 1.198 max γ 1.293 (99%)	$Ar^{40}(n, \gamma)$ (SneA36)
Ar^{42}	33 y sp act (StoeR65) others (HonM64, KatcS52)	☢ $[\beta^-]$ (KatcS52) Δ −34.42 (MTW)	B chem, genet (KatcS52) parent K^{42} (KatcS52)	[daughter radiations from K^{42}]	$Ar^{40}(n, \gamma)Ar^{41}(n, \gamma)Ar^{42}$ (KatcS52) $Ar^{40}(t, p)$ (JarN61)
${}_{19}K^{37}$	1.23 s (SchweF58) 1.25 s (KavR64a) others (SunC58, WallR60, BolF51, LangmR48, TyrH54)	☢ β^+ (BolF51) Δ −24.79 (KavR64a, MTW)	C excit (LangmR48)	β^+ 5.14 max γ 0.511 (200%, $\gamma^\pm$), 2.79 (2.0%)	$Ca^{40}(p, \alpha)$ (WallR60, SunC58, SchweF58, KavR64a)

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$_{19}K^{38}$	7.71 m (EbrT65) 7.67 m (BormM65) 7.7 m (HurD37, RideL37a, GreeD56) others (RamsM47, PerlmM48, SalG63, PhiE65a)	☢ β^+ (HurD37) Δ -28.79 (MTW)	A chem, cross bomb (HurD37, HendW37)	β^+ 2.68 max γ 0.511 (200%, $\gamma^{\pm}$), 2.170 (100%)	$Cl^{35}(\alpha, n)$ (HurD37, RideL37a, HendW37, RamsM47) $Ca^{40}(d, \alpha)$ (HurD37)
K^{38m}	0.95 s (JaneJ61, StahP53b) 0.94 s (LindKH60, KliR54) 0.97 s (MihM58)	☢ β^+ (StahP53, StahP53b) no IT (GoldmD62) Δ -28.66 (LHP, MTW)	C excit (StahP53, StahP53b, KliR54)	β^+ 5.0 max γ 0.511 (200, $\gamma^{\pm}$)	$Cl^{35}(\alpha, n)$ (LindKH60, JaneJ61) $K^{39}(\gamma, n)$ (StahP53b, KliR54, GoldmD62) $Ca^{40}(d, \alpha)$ (JaneJ63, MicS65, HasY59)
$\underline{K^{39}}$		% 93.22 (KenB60) 93.08 (NierA50) others (WhiF56, ReuC56, ReuC52, CookK43) Δ -33.803 (MTW) σ_c 2.0 (GoldmDT64)			
$\underline{K^{40}}$	$t_{1/2}$ 1.26 x 10^9 y assuming $t_{1/2}$ (β^-) = 1.42 x 10^9 y and $\beta^-/(\beta^- + EC)$ = 0.89 $t_{1/2}$ (β^-) sp act: 1.415 x 10^9 y (LeuH65a) 1.42 x 10^9 y (GleL61) 1.37 x 10^9 y (BrinGA65, KonoS55) 1.45 x 10^9 y (MNaiA56) 1.47 x 10^9 y (KellWH59) 1.48 x 10^9 y (FleD62) 1.35 x 10^9 y (SutA55) others (WetG56, SawG50, HouF50, SmaB50, GooML51a, GrafT48, FloyJ49, StouR49, SpierF50, FauWR50, DelC51, MNaiA55) sp act of 1.460 γ: (WetG57, BackeG55a, BurcP53, AhrL48, SutA55, FauWR50, HouF50, SawG49, SpierF50) sp act of EC(K): (HeiJ54)	☢ β^- 89%, EC 11%, β^+ 0.0010% (MNaiA56, EngeD62) β^- 89.5%, EC 10.3%, β^+ 0.00013% (LeuH65a) others (MNaiA55, IngM50b, GrafT51, SutA55, SpierF50, SawG50, CecM50, FauWR50, HouF50, MousuA52, ShilH54, WasG55, AldL56, WasG54, RusR53, ShilH54a, WetG56) % 0.118 (KenB60, ReuC52, ReuC56, WhiF56) 0.119 (NierA50) Δ -33.533 (MTW) σ_c 70 (GoldmDT64)	A chem (ThomJ05, CamN06) chem, mass spect (SmyW37)	β^- 1.314 max β^+ 0.483 max γ Ar X-rays, 1.460 (11%)	
$\underline{K^{41}}$		% 6.77 (KenB60) 6.91 (NierA50) Δ -35.552 (MTW) σ_c 1.2 (GoldmDT64)			
K^{42}	12.36 h (MerJ62) 12.52 h (BurcP53) 12.4 h (SiegK47c, KahB53, MackJ59, HurD37) 12.5 h (WriH57, MonaJ62, SinW51)	☢ β^- (KuriF36) Δ -35.02 (MTW)	A chem, n-capt (AmaE35) chem, cross bomb (HevG35, HevG36) mass spect (AndeG54) daughter Ar^{42} (KatcS52)	β^- 3.52 max γ 0.31 (0.2%), 1.524 (18%)	$K^{41}(n, \gamma)$ (AmaE35, HurD37, SerL47b)
K^{43}	22.4 h (OveR49, AndeG54) 22.0 h (LindqT54)	☢ β^- (OveR49) Δ -36.58 (MTW)	A chem, excit (OveR49) mass spect (AndeG54)	β^- 1.82 max (1%), 1.2 max (3%) 0.83 max γ 0.220 (3%), 0.373 (85%), 0.39 (18%, doublet), 0.59 (13%), 0.619 (81%), 1.01 (2%)	$Ar^{40}(\alpha, p)$ (LasN64, OveR49, BencN59)
K^{44}	22.0 m (CohB54, HilleP61) 22.3 m (SugiyK60) others (WalkH37a, WalkH40b)	☢ β^- (WalkH37a) Δ -36.3 (HilleP61, MTW)	A chem, excit (WalkH37a) chem, sep isotopes, cross bomb (CohB54) mass spect (AndeG54)	β^- 5.2 max γ 1.156 (61%), 1.74 (8%), 2.1 (37%, complex), 2.6 (7%), 3.7 (4%)	$Ca^{44}(n, p)$ (CohB54, WalkH37a, WalkH40b, HilleP61, SugiyK60)
K^{45}	16.3 m (ChacK65) 20 m (MoriH64) 34 m (AndeG54)	☢ β^- (MoriH64) Δ -36.6 (MTW)	B chem, genet energy levels (MoriH64) mass spect (AndeG54)	β^- 4.0 max, 2.1 max γ 0.175 (strong), 0.50, 0.95 (complex?), 1.23, 1.71 (strong), 1.90, 2.1[illegible] 2.35, 2.60, 3.1	$Ca^{48}(d, \alpha n)$ (MoriH64)

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$_{19}K^{47}$	17.5 s (KuroT64)	☢ β^- (KuroT64) Δ −36.3 (MTW)	B chem, sep isotopes, excit (KuroT64,	β^- 6.1 max (1%), 4.1 max γ 2.0 (84%), 2.6 (15%)	$Ca^{48}(\gamma, p)$ (KuroT64)
$_{20}Ca^{37}$	0.173 s (HardJ64a) 0.170 s (ReeP64)	☢ [β^+], p (HardJ64a, ReeP64) Δ −13.3 (ReeP64, MTW)	C excit, decay charac (ReeP64, HardJ64a)	p 3.10	$K^{39}(p, 3n)$ (HardJ64a) $Ca^{40}(p, d2n)$ (HardJ64a) $Ar^{36}(He^3, 2n)$ (ReeP64)
Ca^{38}	0.66 s (CliJ57)	☢ β^+ (CliJ57) Δ −22 (MTW)	C excit, decay charac (CliJ57)	γ 0.511 [200%, $\gamma^\pm$], 3.5 [daughter radiations from K^{38m}]	$Ca^{40}(\gamma, 2n)$ (CliJ57)
Ca^{39}	0.87 s (LindKH60) 0.86 s (MihM58) 0.88 s (KisO58) 0.90 s (KliR54) others (WallR60, SumR53, BraaR53, HubeO43, BagJ64)	☢ β^+ (HubeO43) Δ −27.30 (MTW)	B excit (HubeO43, MElhJ49)	β^+ 5.49 max γ 0.511 (200%, $\gamma^\pm$)	$K^{39}(p, n)$ (KisO58, WallR60) $Ca^{40}(\gamma, n)$ (MihM58, WafH48, HubeO43, MElhJ49, KliR54)
Ca^{40}		% 96.97 (NierA38a) Δ −34.848 (MTW) σ (total absorption) 0.23 (GoldmDT64)			
Ca^{41}	8 x 10^4 y yield (DroJ62) others (BrowF53b)	☢ EC (BrowF51) Δ −35.125 (JohnCH64, MTW)	B chem, n-capt, sep isotopes (BrowF51) others (SaiV51)	γ potassium X-rays	$Ca^{40}(n, \gamma)$ (BrowF51, SaiV51, BrowF53, DroJ62)
Ca^{42}		% 0.64 (NierA38a) Δ −38.540 (MTW) σ (total absorption) 42 (GoldmDT64)			
Ca^{43}		% 0.145 (NierA38a) Δ −38.396 (MTW)			
Ca^{44}		% 2.06 (NierA38a) Δ −41.460 (MTW) σ_c 0.7 (GoldmDT64)			
Ca^{45}	165 d (WyaE61) 167 d (CaliJ59) 153 d (ThirH57) 164 d (DelC53) others (MatthD47, WalkH40b)	☢ β^- (WalkH40b) Δ −40.809 (MTW)	A chem, excit, cross bomb (WalkH40b)	β^- 0.252 max average β^- energy: 0.075 ion ch (CaswR52)	$Ca^{44}(n, \gamma)$ (WalkH40b, SerL47b)
Ca^{46}		% 0.0033 (NierA38a) Δ −43.14 (MTW) σ_c 0.3 (GoldmDT64)			
Ca^{47}	4.535 d (GilmC64) 4.53 d (WyaE61) 4.56 d (GleG64) 4.7 d (LangeL63a, LidL56) others (BatzR51a, MarqL53a, CorkJ53a, LyoW55c)	☢ β^- (MatthD47) Δ −42.35 (MTW)	A chem, genet (BatzR51a) parent Sc^{47} (BatzR51a, CookL53)	β^- 1.98 max (18%), 0.67 max γ 0.49 (5%), 0.815 (5%), 1.308 (74%) daughter radiations from Sc^{47}	$Ca^{46}(n, \gamma)$ (CorkJ53e, CookL53)
Ca^{48}	$t_{1/2}$ (β^-) >1.1 x 10^{18} y sp act (AwsM56) $t_{1/2}$ ($\beta\beta$) >7 x 10^{18} y sp act (DobE59) others (BeliV58, JonJW52, MCarJ55, FremJ52, DobE57, AwsM56)	% 0.185 (NierA38a) Δ −44.22 (MTW) σ_c 1.1 (GoldmDT64)			
Ca^{49}	8.8 m (OKelG56) 8.9 m (MartiDW56a) 8.5 m (DMatE50)	☢ β^- (DMatE50) Δ −41.29 (MTW)	A chem, n-capt, sep isotopes (DMatE50)	β^- 1.95 max γ 3.10 (89%), 4.1 (10%) daughter radiations from Sc^{49}	$Ca^{48}(n, \gamma)$ (DMatE50)

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$_{20}$Ca^{50}	9 s (ShidY64a)	☢ [β^-] (ShidY64a) Δ 41 (ShidY64a, MTW)	C excit, decay charac (ShidY64a)	γ 0.072, 0.258 (with Sc^{50m}) daughter radiations from Sc^{50}	Ca^{48}(t, p) (ShidY64a)
$_{21}$Sc^{40}	0.179 s (SchweF62) 0.22 s (GlasN55) others (TyrH54)	☢ β^+ (GlasN55) Δ −20.3 (RickM65, MTW)	C excit (GlasN55)	β^+ 9.1 max γ 0.511 (200%, $\gamma^\pm$), 3.75 [100%]	Ca^{40}(p, n) (GlasN55, SchweF62)
Sc^{41}	0.60 s (YouD65) 0.55 s (CramJ62) 0.87 s (MartiW52, ElliD41a, WallR60)	☢ β^+ (ElliD41) Δ −28.63 (MTW, JohnCH64)	B excit (ElliD41a, YouD65)	β^+ 5.47 max γ [0.511 (200%, $\gamma^\pm$)]	Ca^{40}(p, γ) (YouD65) Ca^{40}(d, n) (ElliD41a, ElliD41, CramJ62)
Sc^{42}	0.683 s (FreeJ65a) 0.65 s (NelJW65) 0.68 s (CloJ57) 0.69 s (JaneJ61) 0.62 s (MoriH55)	☢ β^+ (MoriH55) Δ −32.109 (FreeJ65a, MTW)	C decay charac (MoriH55) excit (CloJ57, NelJW65)	β^+ [5.41 max] γ 0.511 (200%, $\gamma^\pm$)	K^{39}(α, n) (MoriH55, JaneJ61, NelJW65)
Sc^{42m}	60.6 s (NelJW65) 62.0 s (RogeP63)	☢ β^+ (RogeP63) Δ −31.58 (LHP, MTW, FreeJ65a)	A chem, cross bomb, excit, genet energy levels (RogeP63)	β^+ 2.82 max γ 0.438 (100%), 0.511 (200%, $\gamma^\pm$), 1.22 (100%), 1.52 (100%)	K^{39}(α, n) (RogeP63, NelJW65)
Sc^{43}	3.92 h (HibC45) 3.95 h (DuvJ53) 3.84 h (AndeG54) others (WalkH40)	☢ β^+ (FrisO35), [EC] Δ −36.17 (MTW)	A chem, excit (FrisO35) mass spect (AndeG54)	β^+ 1.20 max γ [Ca X-rays], 0.375 (22%), 0.511 [176%, $\gamma^\pm$]	Ca^{40}(α, p) + Ca^{40}(α, n)Ti^{43}(β^-) (FrisO35, WalkH40)
Sc^{44}	3.92 h (HibC45) 3.90 h (AndeG54) others (BruneJ50, WalkH40, SmiG42)	☢ β^+, EC (HibC45) EC ≈5% (DilL63) ≈3% (KoniJ58c) ≈7% (BluJ55) Δ −37.81 (MTW)	A chem, excit (CorkJ38) mass spect (AndeG54) daughter Ti^{44}, (SharpRA54)	β^+ 1.47 max γ 0.511 (188%, $\gamma^\pm$), 1.159 (100%)	daughter Ti^{44} (SharpRA54, DilL63) daughter Sc^{44m} (KliJ63) K^{41}(α, n) (BruneJ50, WalkH40, HibC43)
Sc^{44m}	2.44 d (HibC45) 2.46 d (AndeG54) others (BruneJ50, WalkH40, RudG52)	☢ IT 98.6%, EC 1.4% (DilL63) Δ −37.54 (LHP, MTW)	A chem, excit, cross bomb (WalkH37) mass spect (AndeG54)	γ Sc X-rays, 0.271 (86%), 1.02 (1.3%), 1.14 (2.7%, doublet) e^- 0.267 daughter radiations from Sc^{44}	K^{41}(α, n) (BruneJ50, WalkH40, HibC43)
Sc^{45}		% 100 (LelW50, HollaR64) Δ −41.061 (MTW) σ_c 13 (to Sc^{46}) 10 (to Sc^{46m}) (GoldmDT64)			
Sc^{46}	83.9 d (GeiKW57) 84.1 d (SchumR56) 84.2 d (WriH57) others (MurH54, AzuR55, WalkH39)	☢ β^-, no EC (MillA47) no β^+, lim 0.0016% (MimW51) Δ −41.756 (MTW)	A n-capt, chem (HevG36) chem, excit, cross bomb (WalkH37b)	β^- 1.48 max (0.004%), 0.357 max γ Ti X-rays, 0.889 (100%), 1.120 (100%)	Sc^{45}(n, γ) (HevG36, WalkH37b, SerL47b)
Sc^{46m}	19.5 s (DMatE51) 20 s (HammR52a, GoldhM48)	☢ IT (GoldhM48) Δ −41.614 (LHP, MTW)	A n-capt, neutron resonance activation (GoldhM48)	γ [Sc X-rays], 0.142 e^- [0.138]	Sc^{45}(n, γ) (GoldhM48)
Sc^{47}	3.43 d (KriN49) 3.44 d (MarqL53a, DuvJ53) 3.40 d (CorkJ53e, MisrS64)	☢ β^- (HibC45a) Δ −44.326 (MTW)	A chem, cross bomb (HibC45a) sep isotopes (KriN49) mass spect (AndeG54) daughter Ca^{47} (BatzR51a, CookL53)	β^- 0.600 max γ 0.160 (73%)	daughter Ca^{47} (BatzR51a, CookL53)
Sc^{48}	1.83 d (WalkH40, KriN49, PouA59, AndeG54, RudG52) 1.84 d (HillmM63) 1.81 d (HibC45a) others (MandeC42)	☢ β^- (WalkH37c) Δ −44.51 (MTW)	A chem, excit (WalkH37c) sep isotopes (KriN49) mass spect (AndeG54)	β^- 0.65 max γ 0.175 (6%), 0.983 (100%), 1.040 (100%), 1.314 (100%)	V^{51}(n, α) (WalkH37c, PoolM37, WalkH40) Ti^{50}(d, α) (KriN49) Ca^{48}(p, n) (HibC45a) Ca^{48}(d, 2n) (SmiG42, MandeC42, MandeC43a)
Sc^{49}	57.5 m (RezI61a) 57 m (WalkH40, OKelG56, KoesL54)	☢ β^- (WalkH40) Δ −46.55 (MTW)	A chem, excit, cross bomb (WalkH40) sep isotopes (KoesL54, OKelG56)	β^- 2.01 max γ 1.76 (0.03%)	Ca^{48}(d, n) (WalkH40)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{21}Sc^{50}$	1.72 m (KantJ63b) 1.7 m (ChilG63) others (KoehD63, MoriH55a) no 23 m activity (KantJ63b, KoehD63)	☢ β^- (MoriH55a) Δ -45.0 (MTW)	C excit (MoriH55a) excit, sep isotopes (KoehD63)	β^- 3.6 max γ 0.520 (100%), 1.12 (100%), 1.55 (100%)	Ti^{50}(n, p) (KoehD63, ChilG63, MoriH55a) Ca^{48}(t, n) (ShidY64a)
Sc^{50m}	0.35 s (KarrM63a, KantJ63b)	☢ IT, no β^-, lim 10% (KarrM63a) Δ -44.7 (LHP, MTW)	C excit, sep isotopes (KarrM63a'	γ 0.258 daughter radiations from Sc^{50}	Ti^{50}(n, p) (KarrM63a) Ca^{48}(t, n) (ShidY64a)
$_{22}Ti^{41}$	0.090 s (ReeP64)	☢ [β^+], p (ReeP64) Δ -15.9 (ReeP64, MTW)	C excit, decay charac (ReeP64)	p 2.3 (! 8), 3.05 (! 17), 3.68 (! 16), 4.12 (! 4), 4.64 (! 50), 5.30 (! 5)	Ca^{40}(He^3, 2n) (ReeP64)
Ti^{43}	0.56 s (JaneJ61) 0.58 s (TyrH54) others (SchelA48, VasiSS61)	☢ β^+ (JaneJ61) Δ -29.3 (MTW)	C excit (SchelA48) excit, decay charac (JaneJ61)	β^+ 5.8 max γ [0.511 (200, $\gamma^{\pm}$)]	Ca^{40}(α, n) (SchelA48, JaneJ61, VasiSS63)
Ti^{44}	48 y (MorelP65) 46 y (WingJ65) others (HuiJ57)	☢ EC (SharpRA54) Δ -37.66 (MTW)	A chem, genet (SharpRA54, HuiJ57, DilL63) parent Sc^{44}, not parent Sc^{44m} (SharpRA54, DilL63, HuiJ57)	γ [Sc X-rays], 0.068 (90%), 0.078 (98%) e^- 0.065, 0.073 daughter radiations from Sc^{44}	Sc^{45}(p, 2n) (SharpRA54, MorelP65) Sc^{45}(d, 3n) (HuiJ57, WingJ65)
Ti^{45}	3.09 h (KunD50a) 3.10 h (RudG52) 3.05 h (TPogM50) others (AlleJS41, PouA59)	☢ β^+, EC (KunD50a) Δ -39.002 (MTW)	A chem, cross bomb, excit (AlleJS41) mass spect (AndeG54)	β^+ 1.04 max γ Sc X-rays, $\gamma^{\pm}$ [170%], 0.718 (0.4%), 1.408 (0.3%)	Sc^{45}(p, n) (AlleJS41, TPogM50, KunD50a) Sc^{45}(d, 2n) (AlleJS41, TPogM50)
Ti^{46}		% 7.99 (HogJ54) 7.95 (NierA38a) Δ -44.123 (MTW) σ (total absorption) 0.6 (GoldmDT64)			
Ti^{47}		% 7.32 (HogJ54) 7.75 (NierA38a) Δ -44 27 (MTW) σ (total absorption) 1.7 (GoldmDT64)			
Ti^{48}		% 73.99 (HogJ54) 73.45 (NierA38a) Δ -48.483 (MTW) σ (total absorption) 8.0 (GoldmDT64)			
Ti^{49}		% 5.46 (HogJ54) 5.51 (NierA38a) Δ -48.558 (MTW) σ (total absorption) 1.9 (GoldmDT64)			
Ti^{50}		% 5.25 (HogJ54) 5.34 (NierA38a) Δ -51.431 (MTW) σ_c 0.14 (GoldmDT64)			
Ti^{51}	5.79 m (SargB53) 5.80 m (BunkM55) others (HammWR53, AteA53b, SegE49, DMatE50, SerL47b)	☢ β^- (SerL47b) Δ -49.74 (MTW)	A n-capt (SerL47b) cross bomb (HammWR53)	β^- 2.14 max γ 0.320 (95%), 0.605 (1.5%), 0.928 (5%)	Ti^{50}(n, γ) (SerL47b, DMatE50)
$_{23}V^{46}$	0.426 s (FreeJ65a) 0.44 s (MillJH58) 0.40 s (MartiW52) 0.37 s (LeiO56) others (TyrH54)	☢ β^+ (MartiW52) Δ -37.069 (FreeJ65a, MTW)	B excit (MartiW52) sep isotopes, excit (JaneJ63a)	β^+ 6.03 max γ 0.511 (200%, $\gamma^{\pm}$)	Ti^{46}(p, n) (JaneJ63a, MartiW52, TyrH54, MillJH58)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{23}V^{47}$	33 m (BaskK62a, KriN49, OConJ42, WalkH37c) 31.1 m (KoesL54) 31 m (DaniH54a)	☢ β^+ (WalkH37c), [EC] Δ -42.01 (MTW)	A chem, excit, cross bomb (OConJ42) chem, sep isotopes (KriN49) mass spect (AndeG54)	β^+ 1.89 max γ 0.511 [192%, $\gamma^\pm$], 1.5 ? (0.7%), 1.80 (0.5%), 2.16 ? (0.2%)	Sc^{45}(α, 2n) Ti^{47}(p, n) (KriN49, OConJ42) Ti^{46}(d, n) (WalkH37c, OConJ42) Ti^{47}(d, 2n) (RuaJ62)
V^{48}	16.0 d (KafP56, WalkH37c) 16.3 d (BurgW54) 16.4 d (MeyPe53) 16.2 d (VNooB57)	☢ β^+ 49%, EC 51% (CassH53) β^+ 56%, EC 44% (VNooB57, HageL57) β^+ 61%, EC 39% (RisR63) others (GooW46, SterM53) Δ -44.470 (MTW)	A chem, excit, cross bomb (WalkH37b, WalkH37c) daughter Cr^{48} (RudG52)	β^+ 0.696 max γ Ti X-rays, 0.511 (100%, $\gamma^\pm$), 0.945 (10%), 0.983 (100%), 1.312 (97%), 2.241 (3%)	Sc^{45}(α, n) (WalkH37b) Ti^{48}(p, n) (DubL40a, TicH52) Ti^{48}(d, 2n) (WalkH37c) Cr^{50}(d, α) (WalkH37c, PeaW46a)
V^{49}	330 d (HaywR56a, LyoW55)	☢ EC (WalkH39) Δ -47.950 (MTW)	B chem (WalkH39, TurL40) chem, excit (HaywR56a, LyoW55)	γ Ti X-rays, continuous bremsstrahlung to 0.60	Cr^{52}(p, α) (LyoW55) Ti^{48}(d, n) (WalkH39)
V^{50}	6 x 10^{15} y sp act (WatD62) 5 x 10^{14} y sp act (BaumE58) $t_{1/2}$ (EC) >8 x 10^{15} y sp act (MNaiA61) $t_{1/2}$ (β^-) >1.2 x 10^{16} y sp act (MNaiA61) others (GloR57a, HeiJ55, CohS52, BaumR56)	☢ EC ≈70%, β^- ≈30% (WatD62) % 0.25 (WhiF56) 0.24 (HessD49, LelW49a) Δ -49.216 (MTW) σ_c 130 (GoldmDT64)	B chem (WatD62)	γ [Ti X-rays], 0.783 (30%), 1.55 (70%)	
V^{51}		% 99.75 (WhiF56) 99.76 (HessD49, LelW49a) Δ -52.199 (MTW) σ_c 4.9 (GoldmDT64)			
V^{52}	3.75 m (BormM65, LBlaJ54, AmaE35) 3.77 m (KoesL54) 3.76 m (SargB53, MalmS63) 3.74 m (MarteJ47) others (KohW65)	☢ β^- (AmaE35) Δ -51.44 (MTW)	A chem, n-capt (AmaE35) cross bomb, excit (WalkH37c)	β^- 2.47 max γ 1.434 (100%)	V^{51}(n, γ) (AmaE35, WalkH37c, PoolM37, SerL47b)
V^{53}	2.0 m (KumI60, SchaA56)	☢ β^- (SchaA56) Δ -51.8 (SchaA56, LHP, MTW)	C decay charac (SchaA56)	β^- 2.50 max γ 1.00 [100%]	Cr^{53}(n, p) (SchaA56)
V^{54}	55 s (SchaA56)	☢ β^- (SchaA56) Δ -50 (MTW)	C decay charac (SchaA56)	β^- 3.3 max γ 0.84 (100%), 0.99 (100%), 2.21 [100%]	Cr^{54}(n, p) (SchaA56)
$_{24}Cr^{46}$	1.1 s (TyrH54)	☢	F excit (TyrH54)		protons on Cr, V (TyrH54)
Cr^{47} (or V^{46})	0.4 s (TyrH54)	☢	F excit (TyrH54)		protons on Cr, V (TyrH54)
Cr^{48}	23 h (VLieR55) 24 h (ShelR55)	☢ EC, no β^+, lim 2% (VLieR55, ShelR55) Δ -43.1 (MTW)	A chem, genet (RudG52) parent V^{48} (RudG52)	γ V X-rays, 0.116 (98%), 0.31 (99%) e^- 0.111, 0.31 daughter radiations from V^{48}	Ti^{46}(α, 2n) (ShelR55)
Cr^{49}	41.9 m (OConJ42) 41.7 m (CrasB53a)	☢ β^+ (OConJ42), [EC] Δ -45.39 (MTW)	A chem, excit, cross bomb (OConJ42)	β^+ 1.54 max e^- 0.058, 0.084, 0.148 γ V X-rays, 0.063 (14%), 0.091 (28%), 0.153 (13%), 0.511 ([186%], $\gamma^\pm$)	Ti^{48}(α, 3n), Ti^{47}(α, 2n) (CrasB53a, NusR54) Ti^{46}(α, n) (OConJ42)
Cr^{50}		% 4.31 (WhiJ48) Δ -50.249 (MTW) σ_c 17 (GoldmDT64)			

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$_{24}Cr^{51}$	27.8 d (SchumR56, GleG64, LyoW52, WriH57) 27.9 d (KafP56) 27.5 d (SalS65)	☢ EC (BradH45b, WalkH40a) no β^+ (BradH45b, KerB49, LyoW52) Δ −51.447 (MTW)	A chem, excit, cross bomb (WalkH40a) daughter Mn^{51} (BurgW50)	γ V X-rays, 0.320 (9%) e^- 0.315	Cr^{50}(n, γ) (SerL47b, WalkH40a)
$\underline{Cr^{52}}$		% 83.76 (WhiJ48) Δ −55.411 (MTW) σ_c 0.8 (GoldmDT64)			
$\underline{Cr^{53}}$		% 9.55 (WhiJ48) Δ −55.281 (MTW) σ_c 18 (GoldmDT64)			
$\underline{Cr^{54}}$		% 2.38 (WhiJ48) Δ −56.931 (MTW) σ_c 0.38 (GoldmDT64)			
Cr^{55}	3.52 m (FlaA52b) 3.6 m (BazG54) 3.59 m (KohW65)	☢ β^- (FlaA52b) Δ −55.11 (MTW)	B chem, cross bomb (FlaA52b)	β^- 2.59 max γ no γ, lim 10%	Cr^{54}(n, γ) (FlaA52b)
Cr^{56}	5.9 m (DroB60)	☢ β^- (DroB60) Δ −55.3 (MTW)	A chem, genet (DroB60) parent Mn^{56} (DroB60)	β^- 1.5 max e^- [0.020, 0.077] γ [Mn X-rays], 0.026, 0.083 daughter radiations from Mn^{56}	Cr^{54}(t, p) (DroB60)
$_{25}Mn^{49}$ (or Cr^{47}, V^{46})	0.4 s (TyrH54)	☢	F excit (TyrH54)		protons on Cr (TyrH54)
Mn^{50}	0.286 s (FreeJ65a) 0.28 s (MartiW52, MillJH58) 0.27 s (TyrH54)	☢ β^+ (MartiW52) Δ −42.618 (FreeJ65a, MTW)	B excit (MartiW52, MillJH58, FreeJ65a)	β^+ 6.61 max γ [0.511 (200%, $\gamma^{\pm}$)]	Cr^{50}(p, n) (MartiW52, MillJH58, TyrH54)
Mn^{50}	2 m (SutD59)	☢ β^+ (SutD59), [EC]	E excit (SutD59)	γ 0.511 (198%, $\gamma^{\pm}$), 0.66 (25%), 0.783 (100%), 1.11 (100%), 1.28 (25%), 1.45 (75%)	Cr^{50}(p, n) (SutD59)
Mn^{51}	45.2 m (KoesL54) 44.3 m (BurgW50) 44 m (NozM60) others (MillDR48, LivJ38d)	☢ β^+ (LivJ37a), [EC] Δ −48.26 (MTW)	A chem, cross bomb (LivJ37a, LivJ38d) chem, genet (BurgW50) parent Cr^{51} (BurgW50)	β^+ 2.17 max γ 0.511 [194%, $\gamma^{\pm}$], 1.56 (?), 2.03 (?)	Cr^{50}(d, n) (LivJ38d, BurgW50) Cr^{50}(p, γ) (DubL38, DelL39)
Mn^{52}	5.60 d (BurgW54) 5.69 d (KafP56) 5.72 d (BackoE55)	☢ EC 66%, β^+ 34% (KoniJ58c, KoniJ58a) EC 71%, β^+ 29% (RemL63, WilsRR62) others (GooW46, SehR54) Δ −50.70 (MTW)	A chem, excit, cross bomb (LivJ37a, LivJ38d)	β^+ 0.575 max γ Cr X-rays, 0.511 (67%, $\gamma^{\pm}$), 0.744 (82%), 0.935 (84%), 1.434 (100%)	Cr^{52}(p, n) (HemA40) Cr^{52}(d, 2n) (PeaW46a, KoniJ58a)
Mn^{52m}	21.1 m (JuliaJ59a) 21.3 m (HemA40) 22.1 m (KayG65)	☢ β^+, IT 2% (KatoT60), [EC] Δ −50.32 (LHP, MTW)	A chem (DarB37) chem, excit, cross bomb (LivJ37a, LivJ38d) daughter Fe^{52} (MillDR48)	β^+ 1.63 max γ 0.383 (2%), 0.511 (193%, $\gamma^{\pm}$), 1.434 (100%)	daughter Fe^{52} (MillDR48, JuliaJ59a)
Mn^{53}	1.9×10^6 y geochemical method (KayJ65) $\approx 2 \times 10^6$ y yield (ShelR57, calc from WilkJR55, DobW56a)	☢ EC (WilkJR55) Δ −54.683 (JohnCH64, MTW) σ_c ≈170 (GoldmDT64)	B chem, decay charac (WilkJR55)	γ Cr X-rays	Cr^{53}(p, n) (WilkJR55) Cr^{52}(d, n) (DobW56a)
Mn^{54}	303 d (MartiWH64) 291 d (BackoE55) 313 d (WyaE61) 278 d (SchumR56) 290 d (KafP56) 300 d (WriH57) others (LivJ38d, SuwS53, SalS65)	☢ EC (AlvL38) no β^+, no β^- (LivJ38d, DeuM44) Δ −55.55 (MTW)	A chem, excit, cross bomb (LivJ37a, LivJ38d)	γ Cr X-rays, 0.835 (100%) e^- 0.829	Fe^{56}(d, α) (LivJ38d, DeuM44) V^{51}(α, n) (LivJ38d) Cr^{53}(d, n) (LivJ38d) Cr^{54}(p, n) (DubL40a)

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$_{25}\mathrm{Mn}^{55}$		% 100 (SamM36a, WhiF56) Δ −57.705 (MTW) σ_c 13.3 (GoldmDT64)			
Mn^{56}	2.576 h (BarthR53a, BarthR53b) 2.574 h (LocE53) 2.586 h (BisG50) others (LivJ38d, BonaG64, BieJ64a, SalS65)	☢ β^- (AmaE35) Δ −56.904 (MTW)	A chem, n-capt (AmaE35) daughter Cr^{56} (DroB60)	β^- 2.85 max γ 0.847 (99%), 1.811 (29%), 2.110 (15%)	Mn^{55}(n, γ) (AmaE35, SerL47b, OrsA49, HumV51)
Mn^{57}	1.7 m (CohB54a, KumI60) 1.9 m (VasiSS63)	☢ β^- (CohB54a) Δ −57.5 (MTW)	B chem, excit (CohB54a)	β^- 2.55 max γ [Fe X-rays, 0.014], 0.122 (strong), 0.136 (strong), 0.22, 0.353, 0.692	Cr^{54}(α, p) (VasiSS63) Fe^{57}(n, p) (CohB54a)
Mn^{57}	7 d (SharmH51)	☢ β^- (SharmH51)	G chem, cross bomb (SharmH51) activity not observed (CohB54a, NelM50)		alphas on Cr, Mn (SharmH51)
Mn^{58}	1.1 m (ChitD61)	☢ β^- (ChitD61) Δ −56 (MTW)	B chem, sep isotopes (ChitD61)	γ 0.36, 0.41, 0.52, 0.57, 0.82, 1.0, 1.25, 1.4, 1.6, 2.2, 2.8	Fe^{58}(n, p) (ChitD61)
$_{26}\mathrm{Fe}^{52}$	8.2 h (JuliaJ59a) 7.8 h (MillDR48)	☢ β^+ 56%, EC 44% (JuliaJ59a) others (ArbE56, FrieG51a) Δ −48.33 (MTW)	A chem, genet (MillDR48) parent Mn^{52m} (MillDR48) not parent Mn^{52}, lim 5% (FrieG51a)	β^+ 0.80 max γ Mn X-rays, 0.165 (100%), 0.511 (112%, $\gamma^{\pm}$) daughter radiations from Mn^{52m} Mn^{52}	Cr^{50}(α, 2n) (FrieG51a)
Fe^{53}	8.51 m (EbrT65) 8.9 m (RideL37a, LivJ38b, JuliaJ59a) 8.6 m (SalS65)	☢ β^+ (RideL37a), [EC] Δ −50.70 (MTW)	A chem (RideL37a) chem, excit, cross bomb (LivJ38b)	β^+ 3.0 max γ 0.38 (32%), 0.511 (196%, $\gamma^{\pm}$)	Cr^{50}(α, n) (NelM50, RideL37a, LivJ38b) Cr^{52}(α, 3n) (JuliaJ59a)
Fe^{54}		% 5.84 (ValleG41a) Δ −56.246 (MTW) σ_c 2.9 (GoldmDT64)			
Fe^{55}	2.60 y (SchumR56) 2.94 y (BrowG50) others (SchumR51a)	☢ EC, no β^+ (BradH46b, MaeD51a, PortF53) Δ −57.474 (MTW)	A chem, excit (LivJ39c) daughter Co^{55} (LivJ41)	γ Mn X-rays, continuous bremsstrahlung to 0.23 (0.004%)	Fe^{54}(n, γ) (EmmW54a)
Fe^{56}		% 91.68 (ValleG41a) Δ −60.605 (MTW) σ_c 2.7 (GoldmDT64)			
Fe^{57}		% 2.17 (ValleG41a) Δ −60.176 (MTW) σ_c 2.5 (GoldmDT64)			
Fe^{58}		% 0.31 (ValleG41a) Δ −62.147 (MTW) σ_c 1.1 (GoldmDT64)			
Fe^{59}	45.6 d (PierA59) 44.5 d (GleG64) 45.1 d (SchumR51a) 45.0 d (TobJ53, TobJ51) 45.5 d (GovJ43) 44.3 d (WriH57) others (WorD63, HeaR60, FusE60, WahA53)	☢ β^- (LivJ38b) Δ −60.660 (MTW)	A chem, excit, cross bomb (LivJ38b)	β^- 1.57 max (0.3%), 0.475 max γ 0.143 (0.8%), 0.192 (2.8%), 1.095 (56%), 1.292 (44%)	Fe^{58}(n, γ) (SerL47b)
Fe^{60}	3 x 10^5 y yield (RoyJ57)	☢ [β^-] (RoyJ57) Δ −61.51 (MTW)	B chem, genet (RoyJ57) parent Co^{60m} (RoyJ57)	daughter radiations from Co^{60m} Co^{60}	protons on Cu (RoyJ57)

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$_{26}Fe^{61}$	6.0 m (StraJ66, RiccE57) others (RiccE55)	☢ β^- (RiccE55, RiccE57) Δ −59 (MTW)	A chem, genet (RiccE55, RiccE57, StraJ66) parent Co^{61} (RiccE55, RiccE57, StraJ66)	β^- 2.8 max γ 0.13 (! 11), 0.30 (! 48), 1.03 (! 98), 1.20 (! 100) daughter radiations from Co^{61}	Ni^{64}(n, α) (RiccE57) Ni^{64}(d, αp) (RiccE57)
$_{27}Co^{54}$	0.194 s (FreeJ65) others (MartiW52, LeiO56, TyrH54)	☢ β^+ (MartiW52) Δ −47.99 (MTW)	C excit (MartiW52, FreeJ65)	β^+ [7.23 max] γ [0.511 (200%, $\gamma^\pm$)]	Fe^{54}(p, n) (FreeJ65, MartiW52)
Co^{54}	1.5 m (SutD59)	☢ β^+ (SutD59)	E excit (SutD59, FreeJ65)	β^+ 4.3 max γ 0.41 (100%), 0.511 (200%, $\gamma^\pm$) 1.14 (100%), 1.41 (100%)	Fe^{54}(p, n) (FreeJ65)
Co^{55}	18.2 h (DarB37) 17.9 h (RudG52) 18.0 h (LivJ41)	☢ β^+ 81%, EC 19% (MukA58) β^+ ≈60%, EC ≈40% (calc from DeuM49) Δ −54.01 (MTW)	A chem (DarB37) chem, cross bomb, genet (LivJ41) parent Fe^{55} (LivJ41)	β^+ 1.50 max γ Fe X-rays, 0.480 (12%), 0.511 (160%, $\gamma^\pm$), 0.930 (80%), 1.41 (13%)	Fe^{54}(d, n) (DarB37, LivJ41, DeuM49) Fe^{54}(p, γ) (LivJ41) Fe^{56}(p, 2n) (MukA58)
Co^{56}	77.3 d (WriH57) 77 d (BurgW54) others (CookCS42, LivJ41)	☢ EC 80%, β^+20% (CookCS56) Δ −56.03 (MTW)	A chem, excit, cross bomb (LivJ41) daughter Ni^{56} (ShelR52, WorW52)	β^+ 1.49 max γ Fe X-rays, 0.511 (40%, $\gamma^\pm$), 0.847 (100%), 1.04 (15%), 1.24 (66%), 1.76 (15%), 2.02 (11%), 2.60 (17%), 3.26 (13%)	Fe^{56}(p, n) (KieP59, GrabZ60a, SakM54) Mn^{55}(α, 3n) (ChenL52a) daughter Ni^{56} (ShelR52, WorW52) Fe^{56}(d, 2n) (LivJ41, JensA41, PleE42, ElliL43a) Ni^{58}(d, α) (LivJ41, CookCS42, ElliL43a)
Co^{57}	270 d (LivJ41) 267 d (CorkJ55)	☢ EC, no β^+, lim 0.002% (CrasB55) Δ −59.339 (MTW)	A chem, excit, cross bomb (LivJ41) daughter Ni^{57} (FrieG52)	γ Fe X-rays, 0.014 (9%), 0.122 (87%), 0.136 (11%), 0.692 (0.14%) e^- 0.007, 0.013, 0.115, 0.129	Ni^{58}(γ, p); Fe^{56}(d, n) (LivJ38a, PerrC38, BarrG39, LivJ41) Fe^{56}(p, γ) (LivJ41) Mn^{55}(α, 2n) (ChenL52a)
Co^{58}	71.3 d (SchumR56) 71.0 d (CorkJ55) 72 d (LivJ41, HoffD52, PreiI60)	☢ EC 85%, β^+ 15% (GooW46, CookCS56) Δ −59.84 (MTW) σ_c 2500 (GoldmDT64)	A chem, excit, cross bomb (LivJ41)	β^+ 0.474 max γ Fe X-rays, 0.511 (30%, $\gamma^\pm$), 0.810 (99%), 0.865 (1.4%), 1.67 (0.6%)	Mn^{55}(α, n) (LivJ38a, LivJ41)
Co^{58m}	9.2 h (ChrisD50) 9.0 h (PreiI60) 8.8 h (StraK50)	☢ IT, no β^+ (StraK50) Δ −59.81 (LHP, MTW) σ_c 1.4×10^5 (GoldmDT64)	A chem, excit (StraK50)	γ Co X-rays e^- 0.017, 0.024	Mn^{55}(α, n) (StraK50)
Co^{59}		% 100 (MitJ41) Δ −62.233 (MTW) σ_c 19 (to Co^{60}) 18 (to Co^{60m}) (GoldmDT64)			
Co^{60}	5.263 y (GorbS63) 5.24 y (GeiKW57) 5.20 y (LocE56) 5.21 y (KasJ53a) 5.27 y (TobJ55, TobJ51) others (LocE53, LivJ41, BrowG50, SinW51)	☢ β^- (RisJ37) Δ −61.651 (MTW) σ_c 6 (GoldmDT64)	A n-capt (SamM36) chem, excit, cross bomb (LivJ41)	β^- 1.48 max (0.12%), 0.314 max (99+%) γ 1.173 (100%), 1.332 (100%)	Co^{59}(n, γ) (RisJ37, LivJ38a, LivJ41, SerL47b, YafL51)
Co^{60m}	10.47 m (BarthR53b) 10.3 m (SchmW63) 10.5 m (PreiI60) 10.7 m (LivJ41)	☢ IT 99+%, β^- 0.25% (SchmW63) IT 99+%, β^- 0.28% (DeuM51) Δ −61.593 (LHP, MTW) σ_c 100 (GoldmDT64)	A n-capt (HeyF37a) chem, excit, cross bomb (LivJ41) daughter Fe^{60} (RoyJ57)	β^- 1.55 max e^- 0.051, 0.058 γ Co X-rays, 0.059 (2.1%), 1.33 (0.25%)	Co^{59}(n, γ) (HeyF37a, LivJ37a, LivJ41, SerL47b)

Isotope Z A	Half-life	Type of decay (✤); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}\equiv 0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{27}Co^{61}$	99.0 m (SmiL51, NerW55) 95 m (StraJ66) 100 m (NusR56) 104 m (ValtA62) others (ParmT49, BrowF53a, HopH50, PreiI60)	✤ β^- (ParmT47) Δ −62.93 (MTW)	A chem, excit, cross bomb, sep isotopes, mass spect (ParmT47) daughter Fe^{61} (RiccE55, RiccE57, StraJ66)	β^- 1.22 max e^- [0.059] γ [Ni X-rays], 0.067 (89%)	$Ni^{64}(p,\alpha)$, $Ni^{64}(d,\alpha n)$, $Ni^{61}(n,p)$ (ParmT47, ParmT49) $Co^{59}(t,p)$ (KunD48)
Co^{62}	13.9 m (ParmT49, GardD57, ValtA62) 13.8 m (PreiI60)	✤ β^- (ParmT49) Δ −61.53 (MTW)	A chem, sep isotopes (ParmT49, GardD57)	β^- 2.88 max γ 1.17 (180%, complex), 1.47 (20%), 1.74 (19%), 2.03 (7%)	$Ni^{64}(d,\alpha)$ (ParmT49, GardD57) $Ni^{62}(n,p)$ (ParmT49, ValtA62)
Co^{62}	1.5 m (ValtA62) 1.6 m (ParmT49) 1.9 m (PreiI60)	✤ β^- (ParmT49)	C cross bomb, sep isotopes (ParmT49)	γ γ rays observed	$Ni^{64}(d,\alpha)$ (ParmT49) $Ni^{62}(n,p)$ (ValtA62, PreiI60, ParmT49)
Co^{63}	52 s (MoriH60)	✤ β^- (MoriH60) Δ −61.9 (MTW)	E chem, excit (MoriH60)	β^- 3.6 max γ no γ, lim 10%	$Ni^{64}(\gamma,p)$ (MoriH60)
Co^{63}	1.40 h (PreiI60) 2.0 h (ValtA62)	✤	G sep isotopes (PreiI60) activity assigned to Co^{61} (StraJ66)		Ni(n, np) (PreiI60, ValtA62)
Co^{64}	28 s (StraJ66)	✤	F excit (StraJ66)	γ 0.095	$Ni^{64}(n,p)$ (StraJ66)
Co^{64}	7.8 m (PreiI60) others (ValtA62, ParmT49)	✤	G sep isotopes (PreiI60) activity not observed (StraJ66) others (ParmT49)		neutrons on $Ni^{(64)}$ (PreiI60)
Co^{64}	2.0 m (PreiI60) others (ValtA62, ParmT49)	✤	G sep isotopes (PreiI60) activity not observed (StraJ66) others (ParmT49)		neutrons on $Ni^{(64)}$ (PreiI60)
$_{28}Ni^{56}$	6.10 d (WelD63) 6.4 d (ShelR52) 6.0 d (WorW52)	✤ EC, no β^+, lim 1% (ShelR52) Δ −53.92 (MTW)	A chem (WorW52) chem, sep isotopes, genet (ShelR52) parent Co^{56} (ShelR52, WorW52)	γ Co X-rays, 0.163 (99%), 0.276 (31%), 0.472 (35%), 0.748 (48%), 0.812 (85%), 1.56 (14%) e^- 0.155 daughter radiations from Co^{56}	$Fe^{54}(\alpha,2n)$ (ShelR52, WorW52, OhnH65, JenkR64)
Ni^{57}	36.0 h (EbrT65) 35.7 h (RudG64) others (MaiF49, LivJ38, FrieG50, ChilG62, RoaJ59, PauA65)	✤ EC 54%, β^+ 46% (KoniJ58c, KoniJ58) EC 50%, β^+ 50% (FrieG50) EC 63%, β^+ 37% (ChilG62) Δ −56.10 (MTW)	A chem, excit, cross bomb (LivJ38) parent Co^{57} (FrieG52)	β^+ 0.85 max γ Co X-rays, 0.127 (14%), 0.511 (92%, $\gamma^{\pm}$), 1.37 (86%), 1.89 (14%) daughter radiations from Co^{57}	$Co^{59}(p,3n)$ (WagG52) $Fe^{54}(\alpha,n)$ (LivJ38, DorR41, NelM42, MaiF49, FrieG50, CanR51c)
Ni^{58}		% 67.76 (WhiJ48) Δ −60.23 (MTW) σ_c 4.4 (GoldmDT64)			
Ni^{59}	8×10^4 y yield (BrosA51) 1×10^5 y yield (SaraB56) 8×10^5 y yield (WilsH51a)	✤ EC (WilsH51a) no β^+, lim 2×10^{-3}% (EmmW54a) Δ −61.159 (MTW)	A chem, cross bomb, n-capt (CamM45) chem, sep isotopes, n-capt (BrosA51)	γ Co X-rays, continuous bremsstrahlung to 1.06	$Ni^{58}(n,\gamma)$ (BrosA51, CamM45, WilsH50) $Co^{59}(d,2n)$ (BrosA51)
Ni^{60}		% 26.16 (WhiJ48) Δ −64.471 (MTW) σ_c 2.6 (GoldmDT64)			
Ni^{61}		% 1.25 (WhiJ48) Δ −64.22 (MTW) σ_c 2 (GoldmDT64)			
Ni^{62}		% 3.66 (WhiJ48) Δ −66.75 (MTW) σ_c 15 (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{28}Ni^{63}$	92 y sp act (HorrD62) 125 y sp act (MMulC56) 85 y yield (BrosA51) 61 y yield (WilsH51a)	☢ β^- (BrosA51) Δ −65.52 (MTW)	A chem, n-capt, sep isotopes (BrosA51)	β^- 0.067 max γ no γ	$Ni^{62}(n, \gamma)$ (BrosA51, WilsH49, WilsH50)
Ni^{64}		% 1.16 (WhiJ48) Δ −67.11 (MTW) σ_c 1.5 (GoldmDT64)			
Ni^{65}	2.564 h (SilL51) 2.55 h (CliJ63a) 2.56 h (ScaR58) 2.50 h (RiccR60b) others (BonaG64, LivJ38, MaiF49, ForS52, NelM42, GrenH65a)	☢ β^- (HeyF37b) Δ −65.14 (MTW)	A n-capt (RotJ36) chem, sep isotopes, excit (SwarJ46, ConnE46)	β^- 2.13 max γ 0.368 (4.5%), 1.115 (16%), 1.481 (25%)	$Ni^{64}(n, \gamma)$ (HeyF37b, ConnE46, DorR41, NelM42, SerL47b, MaiF49)
Ni^{66}	54.8 h (KjeA56) 55 h (JohnN56) 56 h (HopH50, GoeR49)	☢ β^- (GoeR49) Δ −66.06 (MTW)	A chem, genet (GoeR49) parent Cu^{66} (GoeR49)	β^- 0.20 max γ no γ, lim 1% daughter radiations from Cu^{66}	fission (KjeA56, GoeR49, JohnN56)
Ni^{67}	50 s (MeaJL65)	☢ β^- (MeaJL65) Δ −63.2 (MeaJL65, MTW)	C excit (MeaJL65)	β^- 4.1 max γ 0.90 (51%, doublet), 1.26 (15%)	$Zn^{70}(n, \alpha)$ (MeaJL65)
$_{29}Cu^{57}$ (or Co^{54})	0.18 s (TyrH54) 0.14 s (MartiW52)	☢	F excit (TyrH54, MartiW52)		protons on Ni (TyrH54, MartiW52)
Cu^{58}	3.20 s (FreeJ65) 3.04 s (MartiW52) 3.3 s (GerhJ58) others (TyrH54)	☢ β^+ (MartiW52) Δ −51.66 (MTW)	C excit (TyrH54, MartiW52, FreeJ65)	β^+ 8.2 max γ [0.511 (200%, $\gamma^{\pm}$)]	$Ni^{58}(p, n)$ (FreeJ65, MartiW52, TyrH54)
Cu^{58}	9.5 m (YuaT55a) 7.9 m (DelL39) 10.0 m (LeiC47)	☢ β^+ (DelL39, YuaT55a)	G chem (DelL39) chem, excit, sep isotopes (LeiC47) activity cannot be assigned to Cu^{58} from threshold considerations (NDS)		protons on Ni^{58} (LeiC47, DelL39) deuterons on Ni^{58} (YuaT55a)
Cu^{59}	81.5 s (ButlJW58) 81 s (LindnL55, DelL39, LeiC47) others (BudA62, YuaT55a)	☢ β^+, no EC, lim 5% (YuaT55b) Δ −56.36 (MTW)	B chem (DelL39) excit, sep isotopes (LeiC47) genet energy levels (CohB62a, ButlJW58)	β^+ 3.7 max γ 0.343 (5%), 0.463 (5%), 0.511 (197%, $\gamma^{\pm}$), 0.872 (9%), 1.305 (11%), 1.70 (1%)	$Ni^{58}(p, \gamma)$ (LeiC47, DelL39, ButlJW58) $Ni^{58}(d, n)$ (LindnL55)
Cu^{60}	23.4 m (NusR54b) 24.6 m (LeiC47) 24 m (BudA62)	☢ β^+ 93%, EC 7% (NusR54b) Δ −58.35 (MTW)	A chem, excit, sep isotopes, mass spect (LeiC47) daughter Zn^{60} (LindnL55a)	β^+ 3.92 max (6%), 3.00 max (18%), 2.00 max γ Ni X-rays, 0.511 (186%, $\gamma^{\pm}$), 0.85 (15%), 1.332 (80%), 1.76 (52%), 2.13 (6%, doublet), 2.64 (5%), 3.13 (4%), 2.52 (2%), 4.0 (1.0%)	$Ni^{60}(p, n)$ (LeiC47) $Ni^{60}(d, 2n)$ (BudA62, LeiC47, LeviN58)
Cu^{61}	3.32 h (BermA54) 3.33 h (CookCS48b) 3.35 h (BudA62, BoeF50) 3.4 h (ThorRL37, RideL37a, KunD50a) 3.3 h (HopH50)	☢ β^+ 60%, EC 40% (NusR56) others (CookCS51, BouR50, HubeO49, KuzM57) Δ −61.98 (MTW)	A chem, excit (RideL37) chem, excit, sep isotopes (LeiC47, KunD50a) daughter Zn^{61} (LindnL55a, CumJ55, CumJ59)	β^+ 1.22 max e^- 0.059 γ Ni X-rays, 0.067 (4%), 0.284 (12%), 0.38 (3%), 0.511 (120%, $\gamma^{\pm}$), 1.19 (5%)	$Ni^{60}(d, n)$ (ThorRL37) $Co^{59}(\alpha, 2n)$
Cu^{62}	9.76 m (EbrT65) 9.73 m (BermA54) 9.9 m (CriE39, ButlJW58a, PerlmM48, ForS52) 10.1 m (LeiC47, NusR54c) 10.0 m (RideL37a) others (HeyF37a)	☢ β^+ (HeyF37a), [EC] Δ −62.81 (MTW)	A excit (HeyF37a) excit, cross bomb (RideL37a, StraC38, BotW39) chem, sep isotopes (LeiC47) daughter Zn^{62} (MillDR48)	β^+ 2.91 max γ 0.511 (195%, $\gamma^{\pm}$), 0.88 (0.3%), 1.17 (0.5%, complex)	daughter Zn^{62} (MillDR48) $Co^{59}(\alpha, n)$ (RideL37a) $Ni^{62}(p, n)$ (StraC38)
Cu^{63}		% 69.1 (BrowHS47) Δ −65.583 (MTW) σ_c 4.5 (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess $(\Delta \equiv M-A)$, MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{29}$Cu^{64}	12.80 h (TobJ55, RabE50) 12.88 h (SilL51) 12.87 h (WriH57) 12.7 h (SchumR51a) others (BonaG64, BatzR51a, KunD51, HubeO43a, HubeO44a, JohnH50, PerlmM49, StraK51, EdwL52, MillDR48, VVooS36a, HopH50, BeydJ57a, PauA65, ZinH65)	☢ EC 43%, β^- 38%, β^+ 19% (NDS) (β^+ + EC)/β^- 1.6 (ReynJH50) Δ -65.428 (MTW)	A chem, n-capt (AmaE35) excit (VVooS36a) chem, excit (DelL39)	β^- 0.573 max β^+ 0.656 max e^- 1.33 γ Ni X-rays, 0.511 (38%, $\gamma^\pm$), 1.34 (0.5%)	Cu^{63}(n, γ) (HeyF37b, SerL47b)
Cu^{65}		% 30.9 (BrowHS47) Δ -67.27 (MTW) σ_c 2.3 (GoldmDT64)			
Cu^{66}	5.10 m (SargB53) 5.07 m (BarthR53b) 5.12 m (SchumR51a) 5.20 m (KoesL54) 5.2 m (RoderH51, CamAG50) 5.3 m (BormM65) others (FrieG51)	☢ β^- (AmaE35) Δ -66.26 (MTW) σ_c 130 (GoldmDT64)	A n-capt (AmaE35) excit (ChanW37) daughter Ni^{66} (GoeR49)	β^- 2.63 max γ 1.039 (9%)	Cu^{65}(n, γ) (AmaE35, SerL47b, OrsA49, HumV51) daughter Ni^{66} (GoeR49)
Cu^{67}	58.5 h (KunD50a) 61 h (HopH50, EwaG53) 56 h (GoeR49)	☢ β^- (GoeR49) Δ -67.29 (MTW)	A chem (GoeR49) chem, cross bomb, sep isotopes (KunD50a)	β^- 0.57 max e^- 0.082, 0.091 γ Zn X-rays, 0.092 (23%, doublet), 0.184 (40%)	Ni^{64}(α, p) (KunD50a) Zn^{67}(n, p) (KunD50a) Cu^{65}(t, p) (KunD51)
Cu^{68}	30 s (BakH64) 32 s (FlaA53a)	☢ β^- (FlaA53a) Δ -65.4 (MTW)	B chem, excit (FlaA53a) genet energy levels (BakH64)	β^- 3.5 max γ 0.80 (17%), 1.078 (95%), 1.24 (3%), 1.88 (5%)	Ga^{71}(n, α) (FlaA53a, BakH64) Zn^{68}(n, p) (FlaA53a, YthC60c, BakH64)
$_{30}$Zn^{60}	2.1 m (LindnL55a)	☢ [EC, β^+] (LindnL55a)	B chem, genet (LindnL55a) parent Cu^{60} (LindnL55a)		Ni^{58}(α, 2n) (LindnL55a)
Zn^{61}	1.48 m (LindnL55a, CumJ59)	☢ β^+, [EC] (CumJ55, LindnL55a, CumJ59), Δ -56.6 (MTW)	A chem, genet (CumJ55, LindnL55a, CumJ59) parent Cu^{61} (CumJ55, LindnL55a, CumJ59)	β^+ 4.4 max γ 0.48 (11%), 0.511 (198%, $\gamma^\pm$), 0.98 (3%), 1.64 (6%)	Ni^{58}(α, n) (CumJ55, LindnL55a, CumJ59)
Zn^{62}	9.13 h (RudG64) 9.33 h (HaywR50a) 9.3 h (NusR54c) 9.5 h (MillDR48) others (KunD53, PoolM52)	☢ EC ≈82%, β^+ ≈18% (NDS) EC ≈90%, β^+ ≈10% (HaywR50a) Δ -61.12 (MTW)	A chem, genet (MillDR48) excit (GhoS50) parent Cu^{62} (MillDR48)	β^+ 0.66 max e^- 0.033 γ Cu X-rays, 0.042 (20%), 0.51 (47%, doublet, includes $\gamma^\pm$), 0.59 (22%) daughter radiations from Cu^{62}	Cu^{63}(p, 2n) (GhoS50) Cu^{63}(d, 3n) (NusR54c)
Zn^{63}	38.4 m (CumJ61) 38.1 m (RiccR59a) 38.3 m (HubeO47, StraC38, WafH48) 38.5 m (DelL39) 37.6 m (VasiSS61b) others (BotW39, PauA65)	☢ β^+ 93%, EC 11% (HubeO47) Δ -62.22 (MTW)	A chem, excit (BotW37a, HeyF37b, RideL37a) daughter Ga^{63} (NurM65)	β^+ 2.34 max γ Cu X-rays, 0.511 (186%, $\gamma^\pm$), 0.669 (8%), 0.962 (6%), 1.42 (0.9%)	Ni^{60}(α, n) (GhoS50, RideL37a) Cu^{63}(p, n) (StraC38, DelL39, BlasJ51, GhoS50, CumJ61) Cu^{63}(d, 2n) (LivRS40, TownA41)
Zn^{64}	$t_{1/2}$ (EC EC) >8 x 10^{15} y sp act (BertA53)	% 48.89 (BaiK50) Δ -66.000 (MTW) σ_c 0.46 (GoldmDT64)			
Zn^{65}	245 d (TobJ53, PerrC38) 244 d (GeiKW57) 246 d (WriH57, EasH60) 250 d (TatV61, AgarI61)	☢ EC 98.3%, β^+ 1.7% (GleG59, RiccR60b) β^+ 1.2% (BereD62b) Δ -65.92 (MTW)	A chem (PerrC38) chem, excit, cross bomb (LivJ39a) daughter Ga^{65} (LivJ39a)	β^+ 0.327 max e^- 1.106 γ Cu X-rays, 0.511 (3.4%, $\gamma^\pm$), 1.115 (49%)	Zn^{64}(n, γ) (SagR39, SerL47b)
Zn^{66}		% 27.81 (BaiK50) Δ -68.88 (MTW)			
Zn^{67}		% 4.11 (BaiK50) Δ -67.86 (MTW)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{30}Zn^{68}$		% 18.56 (BaiK50) Δ -69.99 (MTW) σ_c 1.0 (to Zn^{69}) 0.1 (to Zn^{69m}) (GoldmDT64)			
Zn^{69}	57 m (LivJ39a) 51 m (HopH48) 52 m (HansA49)	☢ β^- (HeyF37b) Δ -68.43 (MTW)	A chem, n-capt (HeyF37b) chem, excit, cross bomb (LivJ39a, KenJ39) daughter Zn^{69m} (KenJ39)	β^- 0.90 max γ no γ	daughter Zn^{69m} (KenJ39) $Zn^{68}(n, \gamma)$ (HeyF37b, HeyF36, SerL47b, HumV51, SagR39) $Ga^{71}(d, \alpha)$ (LivJ39a)
Zn^{69m}	13.8 h (LivJ39a) others (HopH50, HopH48)	☢ IT (KenJ39) Δ -67.99 (LHP, MTW)	A chem, excit (ThorRL38) chem, excit, cross bomb (LivJ39a, KenJ39) parent Zn^{69} (KenJ39)	γ Zn X-rays, 0.439 (95%) e^- 0.429 daughter radiations from Zn^{69}	$Zn^{68}(n, \gamma)$ (ThorRL38, LivJ39a, SerL47b) $Ga^{71}(d, \alpha)$ (LivJ39a)
Zn^{70}	$t_{1/2}$ ($\beta\beta$) $>10^{15}$ y sp act (FremJ52)	% 0.62 (BaiK50) Δ -69.55 (MTW) σ_c 0.10 (to Zn^{71}) 0.01 (to Zn^{71m}) (GoldmDT64)			
Zn^{71}	2.4 m (ThwT61) 2.2 m (LBlaJ55, HugD46)	☢ β^- (HugD46) Δ -67.5 (MTW)	C n-capt, cross bomb (HugD46) n-capt, sep isotopes (LBlaJ55)	β^- 2.61 max γ 0.120 (0.9%), 0.39 (1.3%), 0.510 (13%), 0.92 (3%), 1.12 (1.3%)	$Zn^{70}(n, \gamma)$ (HugD46, LBlaJ55, ThwT61)
Zn^{71m}	3.92 h (LevkV58) 4.1 h (SonT64) 4.0 h (ThwT61)	☢ β^- (LBlaJ55) Δ -67.2 (LHP, MTW)	A sep isotopes, n-capt (LBlaJ55) chem (SonT64)	β^- 1.46 max γ 0.13 (9%), 0.385 (94%), 0.495 (75%), 0.609 (65%), 0.76 (5%), 0.99 (8%), 1.11 (4%)	$Zn^{70}(n, \gamma)$ (LBlaJ55, ThwT61, TanP64, SonT64)
Zn^{72}	46.5 h (ThwT63) 49 h (SiegJ51) 37 h (IshM63)	☢ β^- (SiegJ51) Δ -68.14 (MTW)	A chem, genet (SiegJ46, SiegJ51) parent Ga^{72} (SiegJ51)	β^- 0.30 max e^- 0.005, 0.014 γ Ga X-rays, 0.015 (8%), 0.046 (weak), 0.145 (90%), 0.192 (10%) daughter radiations from Ga^{72}	fission .(SiegJ51, SteinE51c, GoeR49, FolR51, TurA51a, ThwT63, KjeA63)
$_{31}Ga^{63}$	33 s (NurM65)	☢ [β^+, EC] (NurM65) Δ -57 (MTW)	B chem, excit, cross bomb, genet (NurM65) parent Zn^{63} (NurM65)		$Cu^{63}(\alpha, 4n)$ (NurM65) $Ni^{60}(Li^6, 3n)$ + $Ni^{58}(Li^6, n)$ (NurM65)
Ga^{64}	2.6 m (CrasB53) 2.5 m (CohB53)	☢ β^+, (CrasB53), [EC] Δ -58.93 (MTW)	B chem, cross bomb (CrasB53) chem, excit, sep isotopes (CohB53)	β^+ 6.05 max (33%), 2.8 max γ 0.511 (196%, $\gamma^\pm$), 0.80 (15%), 0.992 (43%), 1.25 (7%), 1.38 (14%), 1.56 (7%), 1.78 (5%), 2.18 (11%), 2.34 (9%), 3.32 (18%)	$Cu^{63}(\alpha, 3n)$ (CrasB53) $Zn^{64}(p, n)$ (CohB53, JacoT60) $Zn^{64}(d, 2n)$ (CrasB53)
Ga^{65}	15.2 m (DaniH57a) 15 m (AlvL38, LivJ39d, CrasB54, KoesL54, PoolM52)	☢ EC (AlvL38) β^+ >50% (AteA52) Δ -62.66 (MTW)	A chem, genet (LivJ39d) parent Zn^{65} (LivJ39d) daughter Ge^{65} (PoriN58)	β^+ 2.24 max (12%), 2.11 max e^- 0.044, 0.053, 0.105 γ Zn X-rays, 0.054 (8%), 0.061 (12%), 0.115 (55%), 0.152 (10%), 0.206 (4%), 0.511 (180%, $\gamma^\pm$), 0.75 (10%), 0.93 (3%)	$Cu^{63}(\alpha, 2n)$, $Zn^{64}(d, n)$, $Zn^{64}(p, \gamma)$ (MorrD59)
Ga^{65}	8.0 m (CrasB54)	☢	G chem, excit, cross bomb (CrasB54) activity not observed (MorrD59)		alphas on Cu, protons on Zn (CrasB54)
Ga^{66}	9.45 h (LangeL50d) 9.3 h (RudG64) 9.5 h (CarvJ59) 9.4 h (RideL37a, BucJ38) 9.2 h (MukA50, MannW37) others (FrauH57b)	☢ β^+ 57%, EC 43% (CamD63) Δ -63.71 (MTW)	A chem, excit (MannW37, RideL37) daughter Ge^{66} (HopH49)	β^+ 4.153 max γ Zn X-rays, 0.511 (114%, $\gamma^\pm$), 0.828 (5%), 1.039 (37%), 1.91 (3%), 2.183 (5%), 2.748 (25%), 4.30 (5%)	$Cu^{63}(\alpha, n)$ (MannW37, RideL37a, LangeL50d)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ=M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{31}$Ga^{67}	77.9 h (TobJ55, TobJ51) 79.2 h (RudG64) 78.2 h (MCowD48) others (HopH50, HopH48, MannW38)	☢ EC (AlvL38) no β^+, lim 0.01% (MeyW53) Δ -66.87 (MTW)	A chem, excit (MannW38, MannW38a) chem, excit, cross bomb (AlvL38) daughter Ge^{67} (HopH49)	γ Zn X-rays, 0.093 (40%), 0.184 (24%), 0.296 (22%), 0.388 (7%) e^- 0.084, 0.092	Zn^{67}(d, n) (AlvL38, ValleG39) Cu^{65}(α, 2n) (HubbJ57)
Ga^{68}	68.3 m (EbrT65) 68.2 m (BormM65) 68 m (RideL37a, PerlmM48, KoesL54)	☢ β^+ 88%, EC 12% (RamasM59a, TayH63a) Δ -67.07 (MTW)	A chem, excit (BotW37a, RideL37a) daughter Ge^{68} (HopH48, HopH50)	β^+ 1.90 max γ Zn X-rays, 0.511 (176%, $\gamma^{\pm}$), 0.80 (0.4%), 1.078 (3.5%), 1.24 (0.14%), 1.87 (0.15%)	daughter Ge^{68} (HopH48) Cu^{65}(α, n) (RideL37a, MannW37) Zn^{68}(p, n) (DubL38, BucJ38, MukA50) Zn^{67} (d, n) (ValleG39)
Ga^{69}		% 60.2 (IngM48b) 60.5 (AntkS53) Δ -69.326 (MTW) σ_c 1.9 (GoldmDT64)			
Ga^{70}	21.1 m (BunkM57) 20 m (AmaE35, MannW38)	☢ β^- (DubL38) Δ -68.90 (MTW)	A chem, n-capt (AmaE35) chem, excit (DubL38)	β^- 1.65 max γ 0.173 (0.16%), 1.040 (0.5%)	Ga^{69}(n, γ) (AmaE35, SerL47b)
Ga^{71}		% 39.8 (IngM48b) 39.5 (AntkS53) Δ -70.135 (MTW) σ_c 5.0 (GoldmDT64)			
Ga^{72}	14.12 h (WyaE61) 14.08 h (BisG50) 14.3 h (SiegJ51, MandeC43a) 14.1 h (SagR39) others (LangeL60)	☢ β^- (SagR39) Δ -68.58 (MTW)	A chem, n-capt, excit (LivJ38b, SagR39) daughter Zn^{72} (SiegJ51)	β^- 3.15 max γ 0.601 (8%), 0.630 (27%), 0.835 (96%), 0.894 (10%), 1.050 (7%), 1.465 (3.5%), 1.60 (5%, complex), 1.860 (5%), 2.201 (26%), 2.50 (20%, doublet)	Ga^{71}(n, γ) (SagR39, SerL47b, SiegJ51)
Ga^{73}	4.9 h (YthC58) 5.1 h (MarqL59) 5.0 h (SiegJ51)	☢ β^- (SiegJ51) Δ -69.74 (MTW)	A chem, excit (SiegJ46, SiegJ51) chem, sep isotopes, cross bomb (YthC58)	β^- 1.19 max e^- 0.012, 0.043, 0.053 γ Ge X-rays, 0.054 (9%), 0.295 (94%), 0.74 (6%) daughter radiations from Ge^{73m} included in above listing	Ge^{73}(n, p) (SiegJ51, YthC58) Ge^{76}(d, αn) (YthC58)
Ga^{74}	8.0 m (YthC59b) 7.8 m (EicE58) others (MarinJ60, MoriH56)	☢ β^- (EicE58) Δ -67.8 (MTW)	A decay charac, excit (MoriH56) chem, sep isotopes, excit, genet energy levels (EicE58, EicE62)	β^- 2.5 max γ 0.50 (11%, complex?), 0.60 (100%, doublet), 0.87 (9%, doublet), 1.11 (5%), 1.20 (8%, doublet), 1.33 (5%), 1.46 (8%, doublet), 1.76 (7%, doublet), 2.35 (45%)	Ge^{76}(d, α) (YthC59b) Ge^{74}(n, p) (MarinJ60, EicE62, EicE58, YthC59b)
Ga^{75}	2.0 m (MoriH60) 1.5 m (YthC60a)	☢ β^- (MoriH60, YthC60a) Δ -68.5 (MoriH60, MTW)	D chem (YthC60a)	β^- 3.3 max γ 0.36 ? (1%), 0.58 (3%) [daughter radiations from Ge^{75}]	Ge^{76}(n, pn) (YthC60a) Ge^{76}(γ, p) (MoriH60)
Ga^{76}	32 s (TakaK61)	☢ β^- (TakaK61)	C genet energy levels (TakaK61)	β^- 6 max γ 0.563, 0.96, 1.12	Ge^{76}(n, p) (TakaK61)
$_{32}$Ge^{65}	1.5 m (PoriN58)	☢ β^+ (PoriN58), [EC] Δ -56 (MTW)	A chem, excit, sep isotopes, genet (PoriN58) parent Ga^{65} (PoriN58)	β^+ 3.7 max γ 0.511 (197%, $\gamma^{\pm}$), 0.67 (3%), 1.72 (2%) daughter radiations from Ga^{65}	Zn^{64}(α, 3n) (PoriN58)
Ge^{66}	2.4 h (RiccR60a) 2.5 h (HopH50) others (RiccR56, ZinH65)	☢ β^+ ≈62%, EC ≈38% (RiccR60a) EC(K) ≈48% (ZinH65) Δ -60.7 (MTW)	A chem, genet (HopH49) parent Ga^{66} (HopH49)	β^+ 2.0 max (<10%), 1.3 max γ Ga X-rays, 0.046 (37%), 0.068 (11%), 0.114 (22%), 0.185 (23%), 0.245 (7%), 0.27 (19%), 0.30 (6%), 0.34 (19%), 0.38 (48%, doublet?), 0.40 (6%), 0.47 (19%), 0.511 (124%, $\gamma^{\pm}$) daughter radiations from Ga^{66}	Zn^{64}(α, 2n) (RiccR60a)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{32}Ge^{67}$	18.7 m (RiccR59) 18.6 m (CogM65) 21 m (HopH50, VasiSS64) 19 m (AteA53) others (RiccR56)	☢ β^+, EC (HopH50, RiccR59) Δ −62.5 (MTW)	A chem, genet (HopH49) parent Ga^{67} (HopH49)	β^+ 3.1 max γ 0.170 (105%, doublet), 0.511 (170%, $\gamma^{\pm}$), 0.84 (4%), 0.92 (7%), 1.48 (5%) daughter radiations from Ga^{67}	Zn^{64}(α, n) (RiccR59)
Ge^{68}	275 d (CrasB56) 250 d (HopH50)	☢ EC (HopH48) no β^+, lim 0.4% (RamasM59a) Δ −67 (MTW)	A chem (MannW38) chem, genet (HopH48) parent Ga^{68} (HopH48, HopH50)	γ Ga X-rays daughter radiations from Ga^{68}	Zn^{66}(α, 2n) (MannW38, RamasM59a, HoreD59)
Ge^{69}	36 h (TemJ65) 40.4 h (NusR57) 38.5 h (SchweC63) 40 h (MCowD48, HopH50) others (MannW38, HubeO44a)	☢ EC ≈67%, β^+ ≈33% (MCowD48) EC(K) ≈55% (ZinH65) Δ −67.101 (MTW)	A chem (MannW38) chem, excit, cross bomb (MCowD48) daughter As^{69} (ButeF55)	β^+ 1.22 max γ Ga X-rays, 0.511 (68%, $\gamma^{\pm}$), 0.573 (13%), 0.872 (10%), 1.107 (28%), 1.335 (3%)	Ga^{69}(d, 2n) (SeaG41, MCowD48, HudC51, TemJ65)
Ge^{70}		% 20.55 (IngM48e) Δ −70.558 (MTW) σ_c 3.2 (GoldmDT64)			
Ge^{71}	11.4 d (MCowD48) 11 d (MandeC49, SeaG41)	☢ EC, no β^+ (MCowD48, MandeC49) Δ −69.90 (MTW)	A chem, excit, cross bomb (SeaG41) sep isotopes, n-capt (ReynS50) daughter As^{71} (HopH49)	γ Ga X-rays	Ge^{70}(n, γ) (SerL47b, MCowD48, MandeC49, ReynS50) Ga^{71}(d, 2n) (SeaG41, MCowD48)
$Ge^{?}$	14 d (LangeM56, LangeM54b)	☢ EC (LangeM56, (LangeM54b)	E chem, critical abs (LangeM56, LangeM54b)	γ Ga X-rays, continuous internal bremsstrahlung to 0.15	neutrons on Ge (LangeM54b, LangeM56)
Ge^{72}		% 27.37 (IngM48e) Δ −72.579 (MTW) σ_c 1.0 (GoldmDT64)			
Ge^{73}		% 7.67 (IngM48e) Δ −71.293 (MTW) σ_c 14 (GoldmDT64)			
Ge^{73m}	0.53 s (CamE57)	☢ IT (CamE57) Δ −71.226 (LHP, MTW)	A n-capt, chem, genet (CamE57) daughter As^{73} (CamE57)	γ Ge X-rays, 0.054 (9%) e^- 0.012, 0.043, 0.053	daughter As^{73} (CamE57)
Ge^{74}		% 36.74 (IngM48e) Δ −73.419 (MTW) σ_c 0.3 (to Ge^{75}) 0.2 (to Ge^{75m}) (GoldmDT64)			
Ge^{75}	82 m (MCowD48) 89 m (SeaG41) 79 m (ReynS50)	☢ β^- (SeaG41) Δ −71.83 (MTW)	A chem, excit, cross bomb (SeaG41) n-capt, sep isotopes (ReynS50)	β^- 1.19 max γ 0.066 (0.3%), 0.199 (1.4%), 0.265 (11%), 0.427 (0.3%), 0.477 (0.3%), 0.628 (0.1%)	Ge^{74}(n, γ) (ReynS50, SmiA52c, SagR39, SagR41, SerL47b) As^{75}(n, p) (SagR41, SeaG41, MCowD48)
Ge^{75m}	48 s (SmiA52c) 49 s (BursS54a) 42 s (FlaA52)	☢ IT (FlaA52) Δ −71.69 (LHP, MTW)	A excit (FlaA52) cross bomb, n-capt, sep isotopes (SmiA52c)	γ Ge X-rays, 0.139 (34%) e^- 0.128, 0.138 daughter radiations from Ge^{75}	Ge^{74}(n, γ) (SmiA52c, FlaA52) As^{75}(n, p) (FlaA52, SmiA52c)
Ge^{76}	$t_{1/2}$ (ββ) >2 × 10^{16} y sp act (FremJ52)	% 7.67 (IngM48a) Δ −73.209 (MTW) σ_c 0.1 (to Ge^{77}) 0.1 (to Ge^{77m}) (GoldmDT64)			

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$_{32}$Ge^{77}	11.3 h (LyoW57) 12 h (SeaG41, SteinE51)	☢ β^- (SagR41) Δ −71.2 (MTW)	A chem, excit, cross bomb (SeaG41) parent As^{77} (SteinE46, SteinE51)	β^- 2.2 max e^- 0.198, 0.253 γ As X-rays, 0.21 (61%, doublet), 0.263 (45%), 0.368 (15%), 0.417 (25%), 0.563 (18%), 0.632 (11%), 0.73 (14%, complex), 0.80 (6%, complex), 0.93 (5%, complex), 1.09 (6%), others to 2.4 daughter radiations from As^{77}	Ge^{76}(n, γ) (LyoW57, ReynS50, SagR39, SagR41, SerL47b)
Ge^{77m}	54 s (LyoW57) 52 s (BursS54a) 59 s (ArnJ47, (VKooJ65) others (ReynS50)	☢ β^- 76%, IT 24% (VKooJ65) β^- 73%, IT 27% (LyoW57) β^- ≈85%, IT ≈15% calc from (BursS54a) Δ −71.0 (LHP, MTW)	A cross bomb, genet, n-capt (ArnJ47) sep isotopes (ReynS50) parent As^{77} (ArnJ47, ReynS50)	β^- 2.9 max e^- 0.148, 0.158 γ Ge X-rays, 0.159 (12%), 0.215 (21%)	Ge^{76}(n, γ) (LyoW57, ReynS50, ArnJ47)
Ge^{78}	1.47 h (FritK65, KvaE65) 1.43 h (SugaN53) 2.1 h (YthC59a, SteinE51)	☢ β^- (SteinE51) Δ −71.8 (KvaE65, MTW)	B chem, genet (SteinE46, SteinE51, YthC59a) parent As^{78} (SteinE46, SteinE51, SugaN53, YthC59a)	β^- 0.71 max γ 0.277 (94%) daughter radiations from As^{78}	fission (SteinE51, FritK65, KvaE65) Se^{82}(n, αn) (YthC59a)
$_{33}$As^{68}	≈7 m (ButeF55)	☢	E chem, excit (ButeF55)		Ge^{70}(p, 3n) (ButeF55)
As^{69}	15 m (ButeF55)	☢ β^+ (ButeF55), [EC] Δ −63.2 (MTW)	B chem, genet (ButeF55) parent Ge^{69} (ButeF55)	β^+ 2.9 max γ 0.23, 0.511 ($\gamma^{\pm}$) daughter radiations from Ge^{69}	Ge^{70}(p, 2n) (ButeF55)
As^{70}	52 m (HopH50, VerkB52) 47 m (SouA55)	☢ β^+ (HopH50) no EC, lim 20% (VerkB52) Δ −64.32 (MTW)	A chem (HopH49, HopH50) chem, decay charac (SouA55) chem (VerkB52) chem, excit (ButeF55) daughter Se^{70} (HopH50)	β^+ 2.89 max (6%), 2.14 max γ [Ge X-rays], 0.511 (183%, $\gamma^{\pm}$), 0.60 (23%), 0.67 (25%), 0.75 (23%), 0.91 (17%), 1.040 (78%), 1.12 (23%), 1.36 (12%), 1.42 (10%), 1.54 (7%), 1.71 (22%), 1.80 (6%), 2.03 (19%), others to 4.7	Ge^{70}(p, n) (ButeF55) Ge^{70}(d, 2n) (VerkB52, BornP63)
As^{71}	62 h (GravW55) 60 h (HopH50, StokP53, BeydJ57a) 65 h (AttH53, ThuS54b)	☢ EC ≈70%, β^+ ≈30% (ThuS54b) EC(K) ≈54% (ZinH65) Δ −67.89 (MTW)	A chem (SagR41) chem, genet (HopH49) mass spect (BracD52) parent Ge^{71} (HopH49)	β^+ 0.81 max e^- 0.012, 0.022, 0.164 γ Ge X-rays, 0.175 (90%), 0.511 (60%, $\gamma^{\pm}$) daughter radiations from Ge^{71}	Ga^{69}(α, 2n) (MeiJ50) Ge^{70}(d, n) (GravW55, ThuS54b, BracD52, MCowD48a)
As^{72}	26 h (MCowD48a) 27 h (HopH50)	☢ EC, β^+ (MCowD48a) EC(K) <30% (ZinH65) Δ −68.22 (MTW)	A chem, excit (MitA47) chem, excit, sep isotopes (MCowD48a) daughter Se^{72} (HopH48, HopH50)	β^+ 3.34 max (17%), 2.50 max e^- 0.679 γ Ge X-rays, 0.511 (150%, $\gamma^{\pm}$), 0.630 (8%), 0.835 (78%), other weak γ's to 3.7 (each <3%)	daughter Se^{72} (HopH48) Ga^{69}(α, n) (MitA47, MCowD48a, MeiJ50, BrunE56)
As^{73}	80.3 d (GleG64) 76 d (MCowD48a) others (SagR39a, MeiJ50)	☢ EC, no β^+, lim 2% (MCowC48a, ElliL43b) Δ −70.92 (MTW)	A chem (SagR39a) chem, excit, cross bomb, sep isotopes (MCowC48a) mass spect (JohaS51a) parent Ge^{73m} (CamE57)	γ Ge X-rays, 0.054 (9%) e^- 0.012, 0.043, 0.053 daughter radiations from Ge^{73m} included in above listing	Ge^{72}(d, n) (SagR39a, JohaS52)
As^{74}	17.9 d (GleG64) 17.5 d (MCowD48a) others (HopH50, SagR39a, MocD48)	☢ β^+ 29%, EC 39%, β^- 32% (GrigE58d) others (GriR59j, HoreD59a, JohaS51, ScoJ57, MeiJ50) Δ −70.855 (MTW)	A excit (CurtB38) chem, excit (SagR39a)	β^- 1.36 max β^+ 1.54 max (3%), 0.95 max (26%) γ Ge X-rays, 0.511 (59%, $\gamma^{\pm}$), 0.596 (61%), 0.635 (14%)	Ga^{71}(α, n) (MCowD48a, HoreD59a)
As^{74m}	8.0 s (SchaA61a)	☢ IT (SchaA61a) Δ −70.572 (LHP, MTW)	B sep isotopes, cross bomb, excit (SchaA61a)	γ 0.283	Ge^{74}(p, n) (SchaA61a) Ge^{73}(p, γ) (SchaA61a)
As^{75}		% 100 (NierA37a) Δ −73.031 (MTW) σ_c 4.5 (GoldmDT64)			

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$_{33}$As^{76}	26.4 h (HubeP53, HubeP52) 26.5 h (DzhB55) 26.3 h (MitA40) 26.8 h (WriH57, WeilG42) 26.1 h (PhiK48)	☢ β^-, no β^+, lim 0.03% (BarbW47) no EC(K), lim 0.02% (ScoJ57) Δ −72.29 (MTW)	A chem, n-capt (AmaE35)	β^- 2.97 max γ 0.559 (43%), 0.657 (6%), 1.22 (5%, doublet), 1.44 (0.7%, doublet), 1.789 (0.3%), 2.10 (0.9%, doublet)	As^{75}(n, γ) (AmaE35, CurtB38, OrsA49, HumV51)
As^{77}	38.7 h (BunkM53, SchmJ55) 38 h (SugaN53, TurA51a) 39 h (EndP54, ReynS53) others (SteinE51)	☢ β^- (SteinE51) Δ −73.92 (MTW)	A chem, genet (SteinE46, SteinE51) daughter Ge^{77} (SteinE51, SteinE46) daughter Ge^{77m} (ArnJ47, ReynS50)	β^- 0.68 max γ 0.086 (0.1%), 0.239 (2.5%), 0.522 (0.8%) daughter radiations from Se^{77m}	Ge^{76}(n, γ) Ge^{77} + Ge^{77m} (β^-) (LyoW57, ArnJ47, ReynS57)
As^{78}	91 m (SugaN53, KjeA59) 90 m (SteinE51, BrigR51) 88 m (CunJ53) others (SneA37, SagR39a, CurtB38)	☢ β^- (SneA37) Δ −72.8 (MTW)	B chem (SneA37) excit (CurtB38) daughter Ge^{78} (SteinE46, SteinE51, SugaN53, YthC59a)	β^- 4.1 max γ 0.614 (I 42), 0.70 (I 15), 0.83 (I 8), 1.31 (I 11)	Br^{81}(n, α) (SneA37, SagR39a, BrigR51) fission (SteinE46, SteinE51) Se^{78}(n, p) (NemY58a)
As^{78m}	6 m (NemY58a)	☢ IT (?) (NemY58a)	G excit (NemY58a) activity not observed (FritK65a)		neutrons on Se^{78} (NemY58a)
As^{79}	9.0 m (CunJ53) 9.1 m (YthC54)	☢ β^- (VHaaP52) Δ −73.7 (MTW)	A chem (ButeF50) chem, genet (YthC54, CunJ53) parent Se^{79m} (YthC54, CunJ53)	β^- 2.15 max γ 0.36 (2%), 0.43 (2%), 0.54 (0.5%), 0.73 (0.5%), 0.89 (1%) daughter radiations from Se^{79m}	Se^{82}(n,α)[Ge^{79}](β^-) (YthC61, YthC54) Se^{80}(n, pn) (VHaaP52, YthC61) Se^{80}(γ, p) (KuroT61a)
As^{80}	15.3 s (MeaRE59) others (YthC54)	☢ β^- (MeaRE59) Δ −71.8 (MTW)	C chem, excit (YthC54) excit, sep isotopes (MeaRE59)	β^- 6.0 max γ 0.666 (42%), 0.8 (1.4%, complex), 1.22 (4%), 1.64 (4%), 1.77 (1.7%)	Se^{80}(n, p) (MeaRE59, YthC54)
As^{81}	33 s (YthC60) 31 s (MoriH60)	☢ β^- (YthC60, MoriH60) Δ −72.6 (MoriH60, MTW)	B chem, excit (MoriH60, YthC60)	β^- 3.8 max γ no γ	Se^{82}(n, pn) (YthC60) Se^{82}(γ, p) (MoriH60)
As^{85}	0.43 s (WanR55)	☢ [β^-], n (WanR55)	F excit (WanR55)		fission (WanR55)
$_{34}$Se^{70}	≈44 m (HopH50)	☢ β^+ (HopH50), [EC]	D chem (HopH49, HopH50) parent As^{70} (HopH50)	γ [As X-rays, 0.511 ($\gamma^{\pm}$)] [daughter radiations from As^{70}]	As^{75}(d, 7n) (HopH50)
Se^{71}	4.5 m (AteA57) 5 m (BeydJ57)	☢ β^+ (BeydJ57), [EC] Δ −63.5 (MTW)	B chem, excit (BeydJ57, AteA57)	β^+ 3.4 max γ 0.16, 0.511 ($\gamma^{\pm}$, [195%])	Ge^{70}(α, 3n) (AteA57) N^{14} on Cu (BeydJ57)
Se^{72}	8.4 d (CumJ58) 9.7 d (HopH50)	☢ EC (HopH50) no β^+, lim 0.1% (CumJ58) Δ −68 (MTW)	A chem, genet (HopH48) parent As^{72} (HopH48, HopH50)	γ As X-rays, 0.046 (59%) e^- 0.034, 0.044 daughter radiations from As^{72}	As^{75}(d, 5n) (HopH48, HopH50) Ge^{70}(α, 2n) (CumJ58)
Se^{73}	7.1 h (CowW48, ScoF51, HaywR56, RiccR60c) others (HopH50)	☢ β^+ 65%, EC 35% (HaywR56, LHP) others (KuzM57, RiccR60c) no IT (RiccR60c) Δ −68.17 (MTW)	A chem (HopH48) chem, excit, sep isotopes (CowW48)	β^+ 1.66 max? (≤0.7%), 1.30 max e^- 0.054, 0.064, 0.347 γ As X-rays, 0.066 (65%), 0.359 (99%), 0.511 (130%, $\gamma^{\pm}$) daughter radiations from As^{73}	Ge^{70}(α, n) (CowC48, ScoF51, RiccR60c) As^{75}(d, 4n) (HopH50)
Se^{73}	42 m (RiccR60c) 44 m (HooF53)	☢ β^+, EC (HooF53, RiccR60c) Δ −68.2 (RiccR60c, MTW)	B chem, excit (ScoF53)	β^+ 1.7 max γ As X-rays, 0.088 ? (6%), 0.251 ? (14%), 0.58 ? (6%)	Ge^{70}(α, n) (RiccR60c) Ge^{72}(α, 3n) (HooF53)
Se^{74}		% 0.87 (WhiJ48) Δ −72.212 (MTW) σ_c 30 (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{34}$Se^{75}	120.4 d (EasH60) 120 d (WriH57, HopH50) 127 d (CowW48) others (CorkJ50f, FrieH47)	☢ EC, no β^+ (FrieH47, CowW48, CorkJ50f) Δ −72.166 (MTW)	A chem, excit (DubL40a, KenC42) sep isotopes, n-capt (CorkJ50f)	γ As X-rays, 0.066 (1.0%), 0.097 (3.3%), 0.121 (17%), 0.136 (57%), 0.265 (60%), 0.280 (25%), 0.401 (12%) e^- 0.085, 0.095, 0.109, 0.124, 0.253	Se^{74}(n, γ) (CorkJ50f, SerL47b, FrieH47) As^{75}(d, 2n) (KenC42, FrieH47, CowW48, HopH50) As^{75}(p, n) (DubL40a)
Se^{76}		% 9.02 (WhiJ48) Δ −75.26 (MTW) σ_c 63 (to Se^{77}) 22 (to Se^{77m}) (GoldmDT64)			
Se^{77}		% 7.58 (WhiJ48) Δ −74.60 (MTW) σ_c 42 (GoldmDT64)			
Se^{77m}	17.5 s (ArnJ47, CanR51a, RutW52) 17.4 s (FlaA50) 17.7 s (AlexKF63) 18.8 s (MalmS62)	☢ IT (ArnJ47) Δ −74.44 (LHP, MTW)	A n-capt (ArnJ47) sep isotopes, n-capt (GoldhM48a) genet (CanR51a) daughter Br^{77} (CanR51a, CanR51c)	γ Se X-rays, 0.161 (50%) e^- 0.148, 0.160	Se^{76}(n, γ) (GoldhM48a, ArnJ47) daughter Br^{77} (CanR51a, CanR51c)
Se^{78}		% 23.52 (WhiJ48) Δ −77.021 (MTW) σ_c 0.05 (to Se^{79}) 0.36 (to Se^{79m}) (GoldmDT64)			
Se^{79}	≤6.5 x 10^4 y sp act (est fission yield) (ParkG49a)	☢ β^- (ParkG49a) Δ −75.921 (MTW)	B chem, decay charac (ParkG49a)	β^- 0.16 max γ no γ	fission (ParkG49a)
Se^{79m}	3.91 m (YthC54) 3.88 m (CunJ53)	☢ IT (FlaA50a) Δ −75.825 (LHP, MTW)	A excit, n-capt (FlaA50, FlaA50a) n-capt, sep isotopes (RutW52) daughter As^{79} (YthC54, CunJ53)	γ Se X-rays, 0.096 (9%, e^- 0.083, 0.095	Se^{78}(n, γ) (RutW52, FlaA50, FlaA50a)
Se^{80}		% 49.82 (WhiJ48) Δ −77.753 (MTW) σ_c 0.5 (to Se^{81}) 0.1 (to Se^{81m}) (GoldmDT64)			
Se^{81}	18.6 m (ApeD57) 18.2 m (YthC54) others (GleL51b, FlaA50, LangsA40, RutW52, WafH48)	☢ β^- (LangsA40) Δ −76.40 (MTW)	A chem, genet (LangsA40) daughter Se^{81m} (LangsA40)	β^- 1.58 max γ 0.030 (0.06%), 0.28 (0.9%, complex), 0.56 (0.3%, complex), 0.83 (∼ 2%)	Se^{80}(n, γ), daughter Se^{81m} (SneA37, LangsA40, SerL47b, SunR62)
Se^{81m}	56.8 m (YthC54) 56.5 m (WafH48) 62 m (ApeD57) 57 m (SneA37, LangsA 40) 61 m (YthC59) others (GleL51b, RutW52, BergI49b)	☢ IT, no β^- (SunR62) IT, [β^-] (YthC59) Δ −76.29 (LHP, MTW)	A chem, excit, cross bomb (SneA37) sep isotopes, n-capt (LeviHA47) mass spect (BergI49b) parent Se^{81} (LangsA40)	γ Se X-rays, 0.103 (8%) e^- 0.090, 0.102 daughter radiations from Se^{81}	Se^{80}(n, γ) (SneA37, HeyF37, SerL47b, LevyHA47;
Se^{82}	>10^{17} y genet (SharmH53)	% 9.19 (WhiJ48) Δ −77.59 (MTW) σ_c 0.004 (to Se^{83}) 0.05 (to Se^{83m}) (GoldmDT64)			
Se^{83}	25 m (GleL51a) 26 m (RutW52) others (LangsA40, YthC54)	☢ β^- (SneA37) Δ −75.4 (CocR59, MTW)	A chem, excit, cross bomb (SneA37) chem, genet (LangsA40) parent Br^{83} (LangsA40, GleL51a)	β^- 1.8 max γ 0.22 (44%), 0.36 (69%), 0.52 ? (59%), 0.71 ? (25%), 0.83 ? (41%, complex), 1.06 ? (16%), 1.31 ? (25%), 1.88 (16%), 2.29 (9%) daughter radiations from Br^{83}, Kr^{83m}	Se^{82}(n, γ) (SneA37, LangsA40, Se-L47b, CocR59)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (△≡M−A), MeV (C¹²≡0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{34}$Se^{83m}	70 s (CocR58) 69 s (RutW52) 67 s (ArnJ47)	☢ β^- (ArnJ47) △ −75.2 (CocR59, MTW)	A chem, genet (ArnJ47) parent Br^{83} (ArnJ47)	β^- 3.8 max γ 0.35 (↑ 16), 0.65 (↑ 20), 1.01 (↑ 100, complex), 2.02 (↑ 40) daughter radiations from Br^{83}, Kr^{83m}	Se^{82}(n, γ) (ArnJ47, CocR58)
Se^{84}	3.3 m (SatJ60)	☢ [β^-] (SatJ60)	A chem, genet (GleL46) parent 31.8 m Br^{84} (GleL51, EdwR51, SatJ60) not parent 6.0 m Br^{84} (SatJ60)		fission (SatJ60)
Se^{85}	39 s genet (SatJ60)	☢ [β^-] (SatJ60)	B chem, genet (SatJ60) parent Br^{85} (SatJ60)		fission (SatJ60)
Se^{87}	16 s (SatJ60)	☢ [β^-] (SatJ60)	D chem, genet (SatJ60) parent Br^{87} (or Br^{86}) (SatJ60)	daughter radiations from Br^{87}	fission (SatJ60)
$_{35}$Br$^{<74}$	4 m (HollaJ53)	☢ (HollaJ53)	E chem, excit (HollaJ53)		C^{12} on Cu (HollaJ53)
Br^{74}	36 m (HollaJ53, GrayJH60) 26 m (ButeF60a) 42 m (BeydJ57a)	☢ β^+, [EC] (HollaJ53) △ −65 (MTW)	B chem, excit (HollaJ53) chem, genet energy levels (BeydJ57a) daughter Kr^{74} (20 m) (GrayJH60) daughter Kr^{74} (12 m) (ButeF60a)	β^+ 4.7 max γ 0.511 ($\gamma^\pm$), 0.64	Cu^{65}(C^{12}, 3n) (HollaJ53)
Br^{75}	1.7 h (BaskK61, WoodwL48a) 1.6 h (HollaJ53, BeydJ57a)	☢ β^+ ≈90%, EC ≈10% (BaskK61) △ −69.44 (MTW)	B chem, cross bomb, sep isotopes (WoodwL48a) daughter Kr^{75} (ButeF60a)	β^+ 1.70 max γ [Se X-rays], 0.285, 0.511 (180%, $\gamma^\pm$), 0.62	Se^{74}(d, n) (WoodwL48a, FulS52, BaskK61) Se^{74}(p, γ) (WoodwL48a) Cu^{65}(C^{12}, 2n) (HollaJ51)
Br^{76}	16.1 h (GirR59c) 16.2 h (DosI63) 16.3 h (ButeF60a) 17.2 h (FulS52) 17.5 h (ThuS55)	☢ β^+ ≈62%, EC ≈38% (DosI63) [β^+ 67%, EC 33%] (GirR59c) EC(K) 20% (KuzM57) △ −70.6 (MTW)	A chem (HopH48a) chem, sep isotopes (FulS52) chem, mass spect (ThuS55) daughter Kr^{76} (CareA54, ThuS55, DosI63)	β^+ 3.6 max γ Se X-rays, 0.511 (133%, $\gamma^\pm$), 0.559 (63%), 0.65 (19%), 0.75 (6%), 0.85 (7%), 1.21 (13%), 1.37 (5%), 1.47 (7%), 1.86 (11%), 2.10 (7%), 2.39 (4%), 2.78 (5%), 2.97 (8%), 3.57 (2%)	As^{75}(α, 3n) (GirR59c)
Br^{77}	57 h (HollaJ51) 58 h (WoodwL48a)	☢ EC 99%, β^+ 1% (SehR54) others (WoodwL48a) △ −73.24 (MTW)	A chem, sep isotopes (WoodwL48a) parent Se^{77m} (CanR51c, CanR51a)	β^+ 0.34 max e^- 0.229, 0.287, 0.508 γ Se X-rays, 0.24 (30%, complex), 0.300 (6%), 0.52 (24%), 0.58 (7%), 0.75 (2%), 0.82 (3%), 1.00 (1.3%) daughter radiations from Se^{77m}	As^{75}(α, 2n) (HollaJ51, CanR51a, MonaS63)
Br^{77m}	4.2 m (GooA59)	☢ IT (GooA59) △ −73.13 (LHP, MTW)	B excit, sep isotopes (GooA59)	γ [Br X-rays], 0.108 e^- 0.094, 0.106 (these radiations were formerly assigned to Br^{78})	Se^{76}(p, γ) (GooA59)
Br^{78}	6.5 m (SchaA61a, RikR61) 6.4 m (SneA37) 6.2 m (PierWu0)	☢ β^+ [92%], EC [8%] (RikR61, PierW60) △ −73.45 (MTW)	A chem, excit (SneA37) cross bomb (PierW60)	β^+ 2.55 max γ Se X-rays, 0.511 (184%, $\gamma^\pm$), 0.614 (14%)	As^{75}(α, n) (SneA37) Se^{78}(p, n) (SchaA61a, RikR61, PierW60, BucJ58, ValleG59) Se^{77}(p, γ) (SchaA61a) Se^{77}(d, n) (SneA37, VasiSS62c)
Br^{78}	<6 m (SneA37)	☢ β^+ (SneA37)	G [genet] (StahP53a) activity not observed (SchaA61a, PierW60)		[daughter Br^{78}] (StahP63a)
Br^{79}		% 50.52 (WilliD46) 50.56 (CamAE55a) △ −76.075 (MTW) σ_c 8.5 (to Br^{80}) 2.9 (to Br^{80m}) (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{35}Br^{79m}$	4.8 s (GooA59) 5.0 s (SchaG54)	☢ IT (SchaG54) Δ −75.87 (LHP, MTW)	B excit (SchaG54) excit, sep isotopes (GooA59)	γ [Br X-rays], 0.21	Se^{78}(p, γ) (GooA59) Br^{79}(n, n') (SchaG54)
Br^{80}	17.6 m (KinA57) 18 m (SneA37, SegE39, AmaE35)	☢ β^- 92%, β^+ 2.6%, EC 5.7% (TrehP62) others (MimW51, ReynJH50, LabJ51, BarbW47) Δ −75.882 (MTW)	A chem, n-capt (AmaE35) chem, excit, cross bomb (SneA37) chem, genet (SegE39) daughter Br^{80m} (SegE39, DVauD40, SidR41)	β^- 2.00 max β^+ 0.87 max γ Se X-rays, 0.511 (5%, $\gamma^{\pm}$), 0.618 (7%), 0.666 (1.0%)	Br^{79}(n, γ), daughter Br^{80m} (SneA37, SerL47b, OrsA49, ALA36, SegE39)
Br^{80m}	4.38 h (KinA57) 4.40 h (SchmW60) 4.6 h (MimW51) others (SneA37, BucJ38, Bo.W39)	☢ IT (SegE39) Δ −75.796 (LHP, MTW)	A chem, n-capt (AmaE35) chem, excit, cross bomb (SneA37) parent Br^{80} (SegE39, DVauD40, SidR41)	γ Br X-rays, 0.037 (36%) e^- 0.024, 0.036, 0.047 daughter radiations from Br^{80}	Br^{79}(n, γ) (AliA36, SneA37, SegE39, SerL47b)
Br^{81}		% 49.48 (WilliD46) 49.44 (CamAE55a) Δ −77.97 (MTW) σ_c 3 (GoldmDT64)			
Br^{82}	35.34 h (MerJ62) 35.9 h (CobJ50) 35.1 h (WintF51) 36.0 h (EerneE50) 35.5 h (WyaE61) 35.7 h (SinW51)	☢ β^- (KurtB35) no EC or β^+, lim 0.03% (ReynJH50) no β^+, lim 0.02% (MimW51) Δ −77.50 (MTW)	A chem, n-capt (KurtB35) chem, excit, cross bomb (SneA37) daughter Br^{82m} (EmeJ65, AndeO65)	β^- 0.444 max γ 0.554 (66%), 0.619 (41%), 0.698 (27%), 0.777 (83%), 0.828 (25%), 1.044 (29%), 1.317 (26%), 1.475 (17%)	Br^{81}(n, γ) (SneA37, KurtB35, SerL47b, EmeJ65)
Br^{82m}	6.05 m (AndeO65) 6.20 m (EmeJ65) 6.2 m (IyeR65)	☢ IT 97.6%, β^- 2.4% (EmeJ65) IT, β^- ≥0.18% (AndeO65) Δ −77.45 (LHP, MTW)	A chem, genet, sep isotopes (AndeO65) genet (EmeJ65) parent Br^{82} (EmeJ65, AndeO65)	γ Br X-rays, 0.046 (0.3%), 0.777 (0.15%), 1.475 (0.009%) β^- [3.138 max] e^- [0.033, 0.044] daughter radiations from Br^{82}	Br^{81}(n, γ) (EmeJ65, AndeO65)
Br^{83}	2.41 h (BowleB61) 2.[illegible] h (PastM63) 2.30 h (SwiP53) 2.4 h (GleL51a, SneA37, VasiI58) 2.3 h (LangsA40, HasR51)	☢ β^- (SneA37) Δ −79.02 (MTW)	A chem, excit (SneA37) daughter Se^{83}, parent Kr^{83m} (LangsA40, StraF40, MoussA41, GleL51a) daughter Se^{83m} (ArnJ47)	β^- 0.93 max γ 0.530 (1.4%) daughter radiations from Kr^{83m}	Se^{82}(n, γ Se^{83}(β^-) (SneA37, LangsA40, GleL51a, BowleB61)
Br^{84}	31.8 m (JohnN57) 31.7 m (SatJ60) others (StraF40, DufR51, KatcS51)	☢ β^- (DodR39) Δ −77.7 (MTW)	A chem (DodR39) chem, excit (BornH43) daughter Se^{84} (GleL51, EdwR51, SatJ60) not parent 6.0 m Br^{84} (SatJ60)	β^- 4.68 max γ 0.81 (9%), 0.88 (51%), 1.01 (10%), 1.21 (4%), 1.90 (18%), 2.47 (8%), 3.93 (13%)	Rb^{87}(n, α) (BornH43, SatJ60) fission (DodR39, HahO39c, HahO39e, StraF40, MoussA41, BornH43, KatcS51)
Br^{84}	6.0 m (SatJ60)	☢ β^- (SatJ60)	A chem, excit, sep isotopes (SatJ60) not daughter Se^{84} (SatJ60) not daughter 31.8 m Br^{84} (SatJ60)	β^- 1.9 max γ 0.44 (68%), 0.88 (75%), 1.46 (75%), 1.89 (16%)	Rb^{87}(n, α) (SatJ60) fission (SatJ60)
Br^{85}	3.00 m (SugaN49) 3.0 m (StraF40, BornH43)	☢ β^- (StraF40) Δ −78.7 (MTW)	A chem (StraF40) chem, genet (SeeW43) parent Kr^{85m} (SeeW43, SugaN49) daughter Se^{85} (SatJ60)	β^- 2.5 max γ no γ daughter radiations from Kr^{85m}	fission (StraF40, BornH43, SeeW43, SugaN49)
Br^{86}	54 s (StehA62, WilliE63)	☢ β^- (StehA62) no n, lim 0.25% (SteinE63) Δ −76 (MTW)	B chem, excit, sep isotopes (StehA62)	β^- 7.1 max γ 1.29 (! 12), 1.36 (! 39), 1.56 (! 100), 1.97 (! 20), 2.34 (! 20), 2.75 (! 36)	Kr^{86}(n, p) (StehA62)
Br^{87}	55.6 s (n) (HugD48) 54.5 s (n) (KeeG57, PerloG59) 55.0 s (n) (RedW47) 56.1 s (β^-) (SugaN49) 55.4 s (n) (WilliE63)	☢ β^-, β^-n (≈2%) (LeviJ51, StehA53) Δ −74.6 (WilliE63, MTW)	A chem (StraF40) chem, genet (BornH43, SugaN49) parent Kr^{87} (BornH43, SeeW43, SugaN49) parent Kr^{86} (2%) (SneA47a, SugaN49) daughter Se^{87} (?) (SatJ60)	β^- 8.0 max(?), 2.6 max n 0.3 (mean energy) γ 1.44 (! 100), 1.85 (! 18), 2.48 (! 18), 2.64 (! 16), 2.98 (! 25), 3.18 (! 16), 3.80 (! 11), 4.19 (! 21), 4.8 (! 17), 5.0 (! 17), 5.2 (! 12) daughter radiations from Kr^{87}	fission (StraF40, SneA47a, SugaN47, SugaN49, RedW47, HugD48)

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$_{35}$Br^{88}	15.5 s (SugaN49) 16.3 s (PerloG59) others (PerloG57, KeeG57)	☢ β^- (SugaN49) n (weak) (PerloG59, PerloG57)	A chem, genet (SugaN49) parent Kr^{88} (SugaN49)	γ 0.76	fission (SugaN49, KeeG57, PerloG59, PerloG57)
Br^{89}	4.5 s (n) (HugD48, RedW47) 4.4 s (n) (PerloG59)	☢ β^-, β^-n (SneA47, HugD48)	D chem (SneA47) parent Kr^{89} (?), parent Kr^{88} (?) (CoryC51)	n 0.5 (mean energy)	fission (SugaN47, SneA47, SugaN49, RedW47, HugD48)
Br^{90}	1.6 s (PerloG59)	☢ [β^-], n (PerloG59)	D chem, decay charac (PerloG59)		fission (PerloG59)
$_{36}$Kr^{74}	20 m (GrayJH60) 12 m (ButeF60a)	☢ β^+, [EC] (GrayJH60) △ −62 (MTW)	B chem, genet (GrayJH60, ButeF60a) parent Br^{74} (36 m) (GrayJH60) parent Br^{74} (26m) (ButeF60a)	β^+ 3.1 max γ 0.511 ($\gamma^\pm$) daughter radiations from Br^{74}	protons on Br (GrayJH60) protons on Sr (ButeF60a)
Kr^{75}	5.5 m (ButeF60a) <1 m (GrayJH60)	☢ [B$^+$, EC] (ButeF60a) △ −64 (MTW)	E chem, genet (ButeF60a) activity not observed (GrayJH60) parent Br^{75} (ButeF60a)		protons on Br (ButeF60a)
Kr^{76}	14.8 h genet (DosI63) 9.7 s (CareA54) 11 h (ThuS55)	☢ EC, no β^+, lim 1% (DosI63) no EC(K) (CareA54) △ −69 (MTW)	A chem, genet (CareA54) chem, mass spect (ThuS55) parent Br^{76} (CareA54, ThuS55, DosI63)	γ [Kr X-rays], 0.039, 0.104, 0.135, 0.267, 0.316, 0.407, 0.452 daughter radiations from Br^{76}	Br^{79}(p, 4n) (ThuS55) Se^{74}(α, 2n) (DosI63)
Kr^{77}	1.19 h (ButeF60a) others (ThuS55, WoodwL48a, BeydJ57a)	☢ EC ≈20%, β^+ ≈80% (ThuS55) others (WoodwL48a) △ −70.4 (MTW)	A chem, sep isotopes (WoodwL48a) chem, mass spect (ThuS55)	β^+ 1.86 max e^- 0.011, 0.023, 0.094 (with Br^{77m}), 0.106 (with Br^{77m}), 0.118, 0.136 γ Br X-rays, 0.024, 0.108 (with Br^{77m}), 0.131, 0.149, 0.665 daughter radiations from Br^{77}	Br^{79}(p, 3n) (ThuS55)
Kr^{78}		% 0.354 (NierA50a) △ −74.14 (MTW) σ_c 2 (to Kr^{79}) (GoldmDT64)			
Kr^{79}	34.92 h (BonaE64) 34.5 h (RadP52) others (WoodwL48, CreEC40a, ChacK61)	☢ EC 92%, β^+ 8% (NDS, BonaE64) others (RadP52a, RadP52b, RadP55, LangeM54, BergI51d, ThuS54c) △ −74.46 (MTW)	A chem (CreEC40a) chem, sep isotopes (WoodwL48) mass spect (BracD52) daughter Rb^{79} (ChacK61)	β^+ 0.60 max e^- 0.031, 0.043, 0.123, 0.204, 0.248, 0.384 γ Br X-rays, 0.136 (0.7%), 0.261 (9%), 0.398 (10%), 0.511 (15%, $\gamma^\pm$), 0.606 (10%), 0.836 (2.0%), 1.119 (0.5%), 1.336 (0.5%)	Br^{79}(p, n) (CreEC40a) Br^{79}(d, 2n) (ClarE44, BonaE64) Kr^{78}(n, γ) (HoaE51a, BergI51d)
Kr^{79m}	55 s (CreEC40a)	☢ IT (?), no β^+ (CreEC40a) △ −74.33 (LHP, MTW)	D chem (CreEC40a)	γ Kr X-rays, 0.127 e^- 0.113, 0.125	Br^{79}(p, n) (CreEC40a)
Kr^{80}		% 2.27 (NierA50a) △ −77.89 (MTW) σ_c 15 (GoldmDT64)			
Kr^{81}	2.1 x 10^5 y sp act, mass spect (EasT64a, ReynJH50a)	☢ EC (ReynJH50a) △ −77.7 (MTW)	A chem, mass spect (ReynJH50a)	γ Br X-rays	Kr^{80}(n, γ) (ReynJH50a, EasT64a)
Kr^{81m}	13 s (ChacK61, CreEC40a) others (KarrD50)	☢ IT, no β^+ (CreEC40a) △ −77.5 (LHP, MTW)	A chem (CreEC40a) genet (KarrD50) daughter Rb^{81} (KarrD50)	γ Kr X-rays, 0.190 (65%) e^- 0.176, 0.188	daughter Rb^{81} (KarrD50)
Kr^{82}		% 11.56 (NierA50a) △ −80.589 (MTW) σ_c 42 (to Kr^{83}) 3 (to Kr^{83m}) (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (♣); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}≡0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{36}Kr^{83}$		% 11.55 (NierA50a) Δ −79.985 (MTW) σ_c 180 (GoldmDT64)			
Kr^{83m}	1.86 h (DVriL52) 1.90 h (BergI51b) 1.88 h (LangsA40) others (RieW46)	♣ IT (LangsA40) Δ −79.943 (LHP, MTW)	A chem, genet (LangsA40) mass spect (BergI50) daughter Br^{83} (LangsA40) daughter Rb^{83} (CastS50)	γ Kr X-rays, 0.009 (9%) e^- 0.007, 0.018, 0.031	daughter Rb^{83} (CastS50)
$\underline{Kr}^{84}$		% 56.90 (NierA50a) Δ −82.433 (MTW) σ_c 0.04 (to Kr^{85}) 0.10 (to Kr^{85m}) (GoldmDT64)			
Kr^{85}	10.76 y (LernJ63) 10.3 y (WanR53) 9.4 y (ThodH48a) others (HoaE51)	♣ β^- (HoaE51) Δ −81.48 (MTW) σ_c <15 (GoldmDT64)	A chem (HoaE51) chem, mass spect (ThodH47)	β^- 0.67 max γ 0.514 (0.41%)	Kr^{84}(n, γ) (HoaE51a) fission (ThodH47, HoaE51)
Kr^{85m}	4.4 h (KocJ49, WoodwL48) 4.5 h (HoaE51a, SneA37) 4.6 h (RieW46, SeeW43)	♣ β^- 77%, IT 23% (BergI51) β^- 78%, IT 22% (BladA55) Δ −81.18 (LHP, MTW)	A chem (SneA37) chem, mass spect (KocJ49) daughter Br^{85} (SeeW43, SugaN49)	β^- 0.82 max e^- 0.134, 0.291 γ Kr X-rays, 0.150 (74%), 0.305 (13%)	Kr^{84}(n, γ) (RieW46, HoaE51a) fission (SeeW43, SugaN49) Se^{82}(α, n) (WoodwL48)
$\underline{Kr}^{86}$		% 17.37 (NierA50a) Δ −83.257 (MTW) σ_c 0.06 (GoldmDT64)	daughter Br^{87} (2%) (SneA47a, SugaN49)		
Kr^{87}	76 m (ClarW64) 78 m (KocJ49) 74 m (SneA37) 75 m (SeeW43, SugaN49)	♣ β^- (SneA37) Δ −80.70 (MTW) σ_c <600 (GoldmDT64)	A chem (SneA37) chem, mass spect (KocJ49) daughter Br^{87} (SeeW43, BornH43, SugaN49)	β^- 3.8 max γ 0.403 (84%), 0.85 (16%), 2.57 (35%)	Kr^{86}(n, γ) (RieW46, HoaE51a) fission, daughter Br^{87} (BornH43, SeeW43, SugaN49)
Kr^{88}	2.80 h (ClarW64) 2.77 h (KocJ49) others (GlasG40, SugaN49)	♣ β^- (LangsA39) Δ −79.9 (MTW)	A chem (HeyF39) chem, genet (LangsA39) chem, mass spect (KocJ49) parent Rb^{88} (LangsA39, AteA39, HeyF39, GlasG40, HahO40, HahO40b) daughter Br^{88} (SugaN49)	β^- 2.8 max e^- 0.013 γ 0.028, 0.166 (7%), 0.191 (35%), 0.36 (5%), 0.85 (23%), 1.55 (14%), 2.19 (≤18%), 2.40 (35%) daughter radiations from Rb^{88}	fission (HeyF39, HahO40, GlasG40, HahO40b)
Kr^{89}	3.18 m (KofO51b) 3.2 m (OckD62) 2.6 m (DilC51a) others (HahO43b)	♣ β^- (GlasG40) Δ −78 (MTW)	A chem, genet (GlasG40, SeeW40) mass spect (KofO51b) parent Rb^{89} (GlasG40, SeeW40, HahO40b, HahO43, BradE51, KofO51b)	β^- 4.0 max γ 0.23 (I 85), 0.36 (I 28), 0.43 (I 29), 0.51 (I 42), 0.60 (I 100), 0.74 (I 32), 0.88 (I 65), 1.12 (I 45), 1.29 (I 31), 1.51 (I 88, complex?), 1.71 (I 34), 1.93 (I 10), 2.04 (I 16), 2.23 (I 10), 2.42 (I 22), 2.57 (I 10) 2.84 (I 25), (some of these may be sum peaks) daughter radiations from Rb^{89}	fission (GlasG40, SeeW40, HahO40b, HahO43, BradE51, KofO51b, AdaRM51)
Kr^{90}	33 s (KofO51b) 35 s (OckD62)	♣ β^- (DilC51) Δ −74.8 (MTW)	A chem, genet (DilC51) mass spect (KofO51b) parent Rb^{90} (KofO51b) ancestor Sr^{90} (DilC51, DilC51a)	β^- 2.80 max γ 0.105 (15%), 0.120 (65%), 0.236 (16%), 0.495 (12%), 0.536 (48%), 1.11 (48%), 1.54 (17%), 1.79 (11%), 2.48 (4%) daughter radiations from Rb^{90}	fission (DilC51, DilC51a, KofO51b, OckD62, GooR64)
Kr^{91}	9.8 s (DilC51a) 10 s (KofO51b) 6 s (OveR51)	♣ β^- (HahO40c)	A chem, genet (HahO40c) mass spect (KofO51b) parent 1.2 m Rb^{91}, parent 14 m Rb^{91} (KofO51b) ancestor Y^{91} (HahO40c, BradE51, DilC51, DilC51a)	β^- 3.6 max γ no γ daughter radiations from 1.2 m Rb^{91}	fission (HahO40c, DilC51a, BradE51, DilC51, AdaRM51)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (△≡M−A), MeV (C^{12} = 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{36}$Kr^{92}	3.0 s (DilC51a)	☢ β^- (HahO40)	B chem, genet (HahO40, DilC51a) ancestor Y^{92}, parent Rb^{92} (DilC51a)		fission (HahO40, DilC51a)
Kr^{93}	2.0 s (DilC51a)	☢ β^- (HahO42)	B chem, genet (HahO42, SelB51) parent Rb^{93} (BradE51, DilC51a, DilC51) ancestor Y^{93} (SelB51)		fission (HahO42, DilC51a, SelB51, BradE51)
Kr^{94}	1.4 s (DilC51a)	☢ β^- (HahO43b)	B chem, genet (HahO43b, DilC51a) parent Rb^{94} (HahO43, HahO43b, DilC51) ancestor Y^{94} (HahO43b, DilC51a)		fission (HahO43b, DilC51a, HahO43)
Kr^{95}	short (DilC51)	☢ [β^-] (DilC51)	F chem, genet (DilC51) parent Rb^{95}, ancestor Zr^{95} (DilC51)		fission (DilC51)
Kr^{97}	≈1 s (DilC51)	☢ β^- (AdaRM51)	G chem, genet (AdaRM51, DilC51) activity not observed (WahA62)		fission (DilC51, AdaRM51)
$_{37}$Rb^{79}	24 m (BeydJ57a, ChamiR57) 21 m genet (ChacK61)	☢ β^+ (BeydJ57), [EC]	A chem (BeydJ57, ChamiR57) chem, genet (ChacK61) parent Kr^{79} (ChacK61)	γ [Kr X-rays], 0.15 (73%), 0.19 (29%), 0.511 ($\gamma^{\pm}$, [180%]), daughter radiations from Kr^{79}	Cu^{65}(O^{16}, 2n) (BeydJ57, ChamiR57) Br^{79}(He^{3}, 3n) (ChacK61)
Rb^{80}	34 s (HoffR61)	☢ β^+, [EC] (HoffR61) Δ −73 (MTW)	A chem, mass spect (HoffR61) daughter Sr^{80} (HoffR61)	β^+ 4.1 max γ 0.513 ($\gamma^{\pm}$, [195%]), 0.618 (39%)	daughter Sr^{80} (HoffR61)
Rb^{81}	4.7 h (KarrD50, DogW56, CastS52)	☢ EC 87%, β^+ 13% (KarrD50) Δ −75.4 (MTW)	A chem, mass spect (ReynF49) parent Kr^{81m} (KarrD50) daughter Sr^{81} (CastS50, CastS52) daughter Rb^{81m} (DogW56) descendant Zr^{81} (ZaitN65)	β^+ 1.03 max γ Kr X-rays, 0.253, 0.450, 0.511 (26%, $\gamma^{\pm}$), 1.10 daughter radiations from Kr^{81m}	Br^{79}(α, 2n) (ReynF49, KarrD50)
Rb^{81m}	31 m (DogW56)	☢ β^+, [EC], IT (DogW56) Δ −75.3 (LHP, MTW)	B chem, genet (DogW56) parent Rb^{81} (DogW56)	β^+ 1.4 mag spect e^- 0.071, 0.083 γ [Rb X-rays, Kr X-rays, 0.085, 0.511 ($\gamma^{\pm}$)] daughter radiations from Rb^{81} Kr^{81m}	Br^{79}(α, 2n) (DogW56)
Rb^{82}	1.25 m (LitL53) 1.3 m (KruP53) 1.1 m (KurcB55)	☢ β^+ 96%, EC 4% (SakM62) Δ −76.42 (MTW)	A chem, genet (LitL53, KruP53) daughter Sr^{82} (LitL53, KruP53, KurcB55)	β^+ 3.15 max γ Kr X-rays, 0.511 (192%, $\gamma^{\pm}$), 0.777 (9%)	daughter Sr^{82} (LitL53, KruP53, KurcB55)
Rb^{82m}	6.3 h (KarrD50) 6.5 h (HancJ40)	☢ EC 94%, β^+ 6% (KarrD50) [EC 79%, β^+ 21%] (NDS) Δ −76.14 (LHP, MTW)	A chem (HancJ40) chem, mass spect (ReynF49) not daughter Sr^{82}, lim 0.1% (LitL53, CastS52)	β^+ 0.78 max γ Sr X-rays, 0.511 ($\gamma^{\pm}$), 0.554 (66%), 0.619 (41%), 0.698 (27%), 0.777 (83%), 0.828 (25%), 1.044 (29%), 1.317 (26%), 1.475 (17%)	Br^{79}(α, n) (HancJ40, ReynF49, KarrD50) Kr^{82}(d, 2n) (HancJ40)
Rb^{83}	83 d (CastS50) 100 d (KurcB55) 107 d (KarrD50)	☢ EC (KarrD50) no β^+ (PerlmM55) Δ −79 (MTW)	A chem, mass spect (KarrD50) daughter Sr^{83}, parent Kr^{83m} (CastS50)	γ Kr X-rays, 0.53 (93%, 3 γ rays), 0.79 (0.9%) e^- 0.007, 0.52 daughter radiations from Kr^{83m}	Br^{83}(α, 2n) (KarrD50) daughter Sr^{83} (CastS50, DosI64a)
Rb^{84}	33.0 d (WelJ55) 34 d (KarrD50)	☢ EC 76%, β^+ 21%, β^- 3% (NDS) Δ −79.753 (MTW)	A chem, cross bomb (BarbW47) chem, mass spect (KarrD50)	β^+ 1.66 max β^- 0.91 max γ Kr X-rays, 0.511 (42%, $\gamma^{\pm}$), 0.88 (74%), 1.01 (0.5%), 1.90 (0.8%)	Br^{81}(α, n) (KarrD50)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{37}$Rb^{84m}	20 m (CohL58, HancJ40) 21 m (CaiR53) 23 m (FlaA50b)	☢ IT, EC (weak) (CaiR53) Δ −79.289 (LHP, MTW)	B chem (HancJ40) chem, excit (FlaA50b)	γ Rb X-rays, 0.216 (37%), 0.250 (65%), 0.464 (32%) e^- 0.201, 0.214, 0.449	Br^{81}(α, n) (HancJ40) Rb^{85}(n, 2n) (FlaA50b)
Rb^{85}		% 72.15 (NierA50a) Δ −82.16 (MTW) σ_c 0.9 (to Rb^{86}) 0.1 (to Rb^{86m}) (GoldmDT64)			
Rb^{86}	18.66 d (EmeE55a, EmeE55) 18.64 d (NidJ55) 18.7 d (WriH57) 18.8 d (GleG64) others (HelmhA41, RobiR58a)	☢ β^- (HelmhA41) Δ −82.72 (MTW)	A chem, n-capt (SneA37) chem, excit (HelmhA41)	β^- 1.78 max γ 1.078 (8.8%)	Rb^{85}(n, γ) (SneA37, ScheiH38, SerL47b)
Rb^{86m}	1.02 m (SchwaR53) 1.06 m (FlaA51)	☢ IT (SchwaR53) Δ −82.16 (LHP, MTW)	B chem, excit, n-capt (FlaA51)	γ [Rb X-rays], 0.56	Rb^{85}(n, γ) (FlaA51, SchwaR53)
Rb^{87}	4.8 x 10^{10} y sp act (KovA65) 4.7 x 10^{10} y sp act (FlyK59, GleL61) 5.2 x 10^{10} y sp act (MNaiA61a, BrinGA65) 5.8 x 10^{10} y sp act (EgeK61, LeuH62a) 5.0 x 10^{10} y Sr^{87}/Rb^{87} ratio (AldL56, OvcG60) 6.2 x 10^{10} y sp act (MGreM54, CurrS51, FliJ54*) 5.1 x 10^{10} y sp act (LibW57) 5.9 x 10^{10} y sp act (LewisG52) 4.3 x 10^{10} y sp act (GeeI54) others (FritK56, StraF38, HaxO48a, HaxO48, KemM49, CharG51, EklS46, BahI52) *corrected for 27.85% abundance (NDS)	☢ β^- (ThomJ05, CamN06) % 27.85 (NierA50a) Δ −84.591 (MTW) σ_c 0.12 (GoldmDT64)	A chem (ThomJ05, CamN06) chem, genet (HahO37, MattaJ37) chem, mass spect (HemA37) parent Sr^{87} (mass spect) (HahO37, MattaJ37)	β^- 0.274 max γ no γ	
Rb^{88}	17.8 m (GlasG40, BunkM51) 17.7 m (ThuS52b) 17.5 m (WeilG42) 18 m (HahO40b, SneA37)	☢ β^- (HahO39c) Δ −82.7 (MTW) σ_c 1.0 (GoldmDT64)	A chem (SneA37) chem, genet (LangsA39, GlasG40, HahO39c) daughter Kr^{88} (HeyF39, LangsA39, GlasG40, HahO40, HahO40b, AteA39)	β^- 5.3 max γ 0.898 (13%), 1.863 (21%), 2.68 (2.3%)	Rb^{87}(n, γ) (SneA37, PoolM37, ScheiH38, SerL47b) fission, daughter Kr^{88} (HeyF39, LangsA39, GlasG40, HahO40, HahO40b)
Rb^{89}	15.4 m (GlasG40) 14.9 m (OKelG56a) 15.5 m (HahO40b)	☢ β^- (GlasG40) Δ −82.3 (MTW)	A chem, genet (GlasG40, SeeW40) daughter Kr^{89} (GlasG40, SeeW40, HahO40b, HahO43, BradE51, KofO51b) parent Sr^{89} (GlasG40, HahO40, HahO43, HahO40b, GrumW46)	β^- 3.92 max (7%), 2.9 max (5%), 1.6 max γ 0.66 (17%), 1.05 (75%), 1.26 (54%), 2.20 (14%), 2.59 (13%)	fission (GlasG40, SeeW40, HahO40b, HahO43, BradE51)
Rb^{90}	2.91 m (JohnN64) 2.74 m (KofO51b) 2.8 m (OckD62)	☢ β^- (KofO51b) Δ −79.3 (MTW)	A chem, genet (KofO51b) daughter Kr^{90}, parent Sr^{90} (DilC51, DilC51a, KofO51b)	β^- 6.6 max γ 0.53 (4%), 0.83 (61%, doublet), 1.03 (5%), 1.11 (7%), 1.40 (5%), 1.70 (3%), 3.07 (5%), 3.34 (15%, doublet), 3.54 (5%), 4.13 (11%), 4.34 (18%, doublet), 4.60 (5%), 5.2 (4%)	fission (KofO51b, DilC51, DilC51a, JohnN64, OckD62)
Rb^{91}	1.2 m (JohnN64, WahA62) 1.7 m (KofO51b)	☢ β^- (KofO51b) Δ −78 (MTW)	A chem, genet (KofO51b) daughter Kr^{91}, parent Sr^{91} (KofO51b) ancestor Y^{91} (DilC51, HahO40c)	β^- 4.6 max	fission (KofO51b, DilC51, HahO40c, WahA62, JohnN64)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV (C^{12} = 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{37}$Rb^{91}	14 m (KofO51b) activity not observed (WahA62)	☢ β^- (KofO51b)	E chem, genet (KofO51b) daughter Kr^{91}, parent Sr^{91} (KofO51b) no 14 m Rb parent of Sr^{91} (WahA62)		fission (KofO51b)
Rb^{92}	5.3 s genet (FritK60) others (BradE51, DilC51a, HahO40)	☢ [β^-] (DilC51a) Δ -75 (MTW)	B genet (DilC51a) chem, genet (FritK60) daughter Kr^{92}, ancestor Y^{92} (DilC51a) parent Sr^{92} (FritK60)		fission (FritK60) DilC51a)
Rb^{93}	5.6 s (FritK60)	☢ [β^-] (HahO42)	B chem, genet (FritK60) parent Sr^{93}, ancestor Y^{93} (FritK60) daughter Kr^{93} (BradE51, DilC51a, DilC51)		fission (FritK60)
Rb^{94}	2.9 s (FritK61) others (DilC51a, HahO43b, HahO43)	☢ [β^-] (HahO43b, HahO43, FritK61)	B chem, genet (FritK61) ancestor Y^{94} (FritK61) daughter Kr^{94}, ancestor Y^{94} (HahO43, HahO43b, DilC51)		fission (FritK61)
Rb^{95}	<2.5 s (FritK61)	☢ [β^-] (DilC51)	F genet (DilC51) daughter Kr^{95}, ancestor Zr^{95} (DilC51)		fission (DilC51)
$_{38}$Sr^{80}	1.7 h (HoffR61)	☢ EC (HoffR61)	A chem, genet (HoffR61) parent Rb^{80} (HoffR61)	γ [Rb X-rays], 0.58 daughter radiations from Rb^{80}	N^{14} on Ga (HoffR61)
Sr^{81}	29 m (CastS50, CastS52)	☢ EC, β^+ (CastS50)	B chem, genet (CastS50, CastS52) parent Rb^{81} (CastS50, CastS52) descendant Zr^{81} (ZaitN65)	γ [Rb X-rays, 0.511 ($\gamma^{\pm}$)] daughter radiations from Rb^{81} Kr^{81m}	Rb^{85}(p, 5n) (CastS50, CastS52)
Sr^{82}	25.0 d (SanV58) 25.5 d (KruP53) others (MacIK52, LitL53, CastS50)	☢ EC, no β^+, lim 5% (KurcB55) Δ -76 (MTW)	A chem, excit (CastS50) mass spect (MLurK52) parent Rb^{82}, not parent Rb^{82m}, lim 0.1% (CastS52, LitL53, KruP53, KurcB55) daughter Y^{82} (MaxV62, ButeF63) descendant Zr^{82} (ZaitN65)	γ Rb X-rays daughter radiations from Rb^{82}	Rb^{85}(p, 4n) (CastS50, CastS52) As^{75}(C^{12}, 5n)Y^{82}(EC) (MaxV62)
Sr^{83}	32.4 h (DosI64) 32.9 h (KuroT61) others (KurcB55, CastS50, MacIK52, ButeF63, MaxV62)	☢ EC 84%, β^+ 16% (KuroT61) Δ -77 (MTW)	A chem, genet (CastS50) mass spect (MLurK52) parent Rb^{83} (CastS50) daughter Y^{83} (MaxV62, DosI64a, NiecW65) descendant Zr^{83} (ZaitN65)	β^+ 1.15 max e^- 0.025, 0.040 γ Rb X-rays, 0.040 (24%), 0.38 (35%), 0.511 (32%, $\gamma^{\pm}$), 0.76 (40%), 1.16, 1.52 daughter radiations from Rb^{83}	Rb^{85}(p, 3n) (CastS52)
Sr^{84}		% 0.56 (NierA38b) 0.55 (AldL53) Δ -80.638 (MTW) σ_c 0.8 (to Sr^{85}) 0.65 (to Sr^{85m}) (GoldmDT64)			
Sr^{85}	64.0 d (WriH57) 64.9 d (GleG64) 63.9 d (SatA62a) 65 d (HerrmG56, TPogM51) 66 d (DubL40)	☢ EC (TPogM51, BisA56f) no β^+ (TPogM51) Δ -81.05 (MTW)	A chem, excit (DubL40) daughter Y^{85} (DosI63a, CareA52, NiecW65)	γ Rb X-rays, 0.514 (100%) e^- 0.499	Sr^{84}(n, γ) (SatA62a) Rb^{85}(p, n) (DubL40) Rb^{85}(d, 2n) (TPogM51, EmmW52)
Sr^{85m}	70 m (DubL40)	☢ IT 86%, EC 14% (SunA52) Δ -80.81 (LHP, MTW)	A chem, excit (DubL40) daughter Y^{85m} (MaxV62, DosI63a, NiecW65) descendant 15 m Zr^{85} (ButeF63)	γ Rb X-rays, Sr L X-rays, 0.150 (14%), 0.231 (85%) e^- 0.005, 0.134, 0.215	Sr^{84}(n, γ) (SunA52) Rb^{85}(p, n) (DubL40) Rb^{85}(d, 2n) (TPogM51)

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$_{38}\mathrm{Sr}^{86}$		% 9.86 (NierA38b) 9.87 (AldL53) Δ -84.499 (MTW) σ_c 1.3 (to Sr^{87m}) (GoldmDT64)			
Sr^{87}		% 7.02 (NierA38b, AldL53) Δ -84.865 (MTW)	daughter Rb^{87} (mass spect) (HahO37, MattaJ37)		
Sr^{87m}	2.83 h (BormM65) 2.80 h (MannL51, HydE51) 2.88 h (GravG52) others (HerrmG56, DubL40)	☢ IT 99+%, EC(K) 0.6% (SunA60) Δ -84.477 (LHP, MTW)	A chem, excit (StewD37) chem, excit, cross bomb, genet (DubL40) daughter Y^{87} (DubL39, DubL40, MannL50, MannL51, LindnM50a, HydE51)	γ Sr X-rays, 0.388 (80%) e^- 0.372, 0.386	daughter Y^{87} (DubL39, MannL50, MannL51) Sr^{86}(n, γ) (StewD37, DubL39, RedH40, RedH40a) Rb^{87}(p, n) (DubL39)
Sr^{88}		% 82.56 (NierA38b, AldL53) Δ -87.89 (MTW) σ_c 0.006 (GoldmDT64)			
Sr^{89}	52.7 d (FlyK65a) 50.4 d (OsmR59) 53.6 d (SatA62) 50.5 d (HerrmG54, HerrmG55) others (KjeA56, NoveT51, LieC39, StewD39, GoeR49, GrumW46)	☢ β^- (StewD37) Δ -86.22 (MTW) σ_c 0.4 (GoldmDT64)	A chem, excit (StewD37) chem, mass spect (HaydR48) daughter Rb^{89} (GlasG40, HahO40, HahO40b, HahO43, GrumW46) parent Y^{89m} 0.009% (SatA62); 0.02% (LyoW55b); 0.01% (HerrmG56); <0.0005% (BisA55d)	β^- 1.463 max γ 0.91 (0.009%, with Y^{89m})	Sr^{88}(d, p) (StewD37, StewD39) Sr^{88}(n, γ) (SerL47b, StewD37, StewD39)
Sr^{89m}	10 d (HerrmG54, HerrmG55)		G activity not observed (HerrmG56, SatA62, FleJ62)		
Sr^{90}	27.7 y sp act, mass spect (WileDM55) 28.0 y (FlyK65) 28.4 y (ReeG55) others (AniM58, PowR50)	☢ β^- (NotR51) Δ -85.95 (MTW, LHP) σ_c 1 (GoldmDT64)	A chem, genet (HahO42) chem, mass spect (HaydR48) daughter Rb^{90} (DilC51, DilC51a, KofO51b) parent Y^{90} (HahO42, HahO43, GrumW46, NotR51) descendant Kr^{90} (DilC51, DilC51a)	β^- 0.546 max γ no γ daughter radiations from Y^{90}	fission (DilC51, DilC51a, KofO51b, GrumW46, GrumW48)
Sr^{91}	9.67 h (AmeD53) 9.7 h (HerrmG54, HerrmG55, FinB51, VasiI58, BakH65) others (HahO43)	☢ β^- (GotH41) Δ -83.68 (MTW)	A chem, genet (GotH41) chem, excit (SeeW43b) parent Y^{91m}, parent Y^{91} (GotH41, HahO43, FinB51) daughter 1.2 m Rb^{91}, daughter 14 m Rb^{91} (KofO51b) no 14 m Rb parent of Sr^{91} (WahA62)	β^- 2.67 max γ 0.645 (15%), 0.748 (27%), 0.93 (3%), 1.025 (30%), 1.413 (5%) daughter radiations from Y^{91m}, Y^{91}	fission (GotH41, HahO43, FinB51, KatcS48, FinB51c) Zr^{94}(n, α) (SeeW43b)
Sr^{92}	2.71 h (FritK60) 2.60 h (HerrmG56) 2.7 h (GotH41)	☢ β^- (GotH41) Δ -82.9 (MTW)	A chem, genet (GotH41) parent Y^{92} (GotH41, HoaE51b) daughter Rb^{92} (FritK60)	β^- 1.5 max (10%), 0.55 max γ 0.23 (3%), 0.44 (4%), 1.37 (90%) daughter radiations from Y^{92}	fission (HahO40, HahO43, HahO43b, KatcS51a, BradE51, KatcS48)
Sr^{93}	8.3 m (ValliD61) 7.5 m (FritK60) 8.5 m (BakH65) 8 m (KniJD59) 7 m (LieC39)	☢ β^- (LieC39) Δ -79.4 (MTW, SteinE65)	A chem (LieC39, HahO43) chem, sep isotopes (BakH65) parent Y^{93} (HahO43, HahO43b, KniJD59) daughter Rb^{93} (FritK60)	β^- 4.8 max ? (weak), 2.9 max γ 0.60, 0.8, 1.2, others between 0.2 and 3.0 daughter radiations from Y^{93}	Zr^{96}(n, α) (ValliD61, BakH65) fission (LieC39, HahO42, HahO43, KniJD59)
Sr^{94}	1.35 m (FritK61) 1.2 m (HovD64) 1.3 m (KniJD59)	☢ β^- (HahO43b, HahO43) Δ -78.8 (MTW)	A chem, genet (HahO43b, HahO43) parent Y^{94} (HahO43, HahO43b, KniJD59)	β^- 2.1 max γ 1.42 (100%) daughter radiations from Y^{94}	fission (HahO43, HahO43b, DilC51, KniJD59, FritK61, HovD64)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification, Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{38}$Sr^{95}	0.8 m genet (FritK61)	☢ β^- (DilC51)	B genet (DilC51) chem (FritK61) ancestor Zr^{95}, descendant Kr^{95} (DilC51) parent Y^{95} (FritK61)		fission (DilC51, FritK61)
$_{39}$Y^{82}	12.3 m genet (ButeF63) 9 m genet (MaxV62) <1.5 m genet (not observed) (NiecW65)	☢ [EC, β^+] (MaxV62, ButeF63)	B chem, genet (MaxV62, ButeF63) parent Sr^{82} (MaxV62, ButeF63) daughter Zr^{82} (ZaitN65)		As^{75}(C^{12}, 5n) (MaxV62) protons on Y^{89} (ButeF63)
Y^{82}	70 m (CareA52)		G chem, genet (CareA52) activity not observed (MaxV62, ButeF63)		protons on Y (CareA52)
Y^{83}	7.4 m genet (DosI64a) 7.5 m genet (NiecW65) 8 m genet (MaxV62)	☢ [EC, β^+] (MaxV62)	A chem, genet (MaxV62, DosI64a, NiecW65) parent Sr^{83} (MaxV62, DosI64a, NiecW65)		As^{75}(C^{12}, 4n) (MaxV62) Sr^{84}(p, 2n) (DosI64a)
Y^{83}	3.5 h (CareA52)		G chem, genet (CareA52) activity not observed (DosI64a, NiecW65)		protons on Y (CareA52)
Y^{83}	35 m (ButeF63)		G chem, genet (ButeF63) activity not observed (DosI64a, NiecW65)		protons on Y (ButeF63)
Y^{84}	43 m (YamaT62) 39 m (MaxV62)	☢ β^+, [EC] (YamaT62) Δ −74.3 (MTW)	A chem, excit, cross bomb (MaxV62) chem, excit (YamaT62) daughter Zr^{84} (ZaitN65)	β^+ 3.5 max γ [Sr X-rays], 0.511 (strong, $\gamma^{\pm}$), 0.590 (15%), 0.795 (100%), 0.982 (100%), 1.041 (50%), 1.27 (9%), 1.47 (6%)	As^{75}(C^{12}, 3n) (MaxV62) Sr^{84}(d, 2n) (MaxV62) Sr^{88}(p, 5n) (YamaT62)
Y^{84}	3.7 h (RobeB49) 2.6 h (ButeF63)		G chem, excit, sep isotopes (RobeB49) assigned to Y^{85m} (MaxV62, YamaT62)		deuterons, protons on Sr^{84} (RobeB49)
Y^{85}	5.0 h (DosI63a) 4.9 h (NiecW65) 5 h (CareA52)	☢ β^+ 70%, EC 30%, no IT, lim 1% (DosI63a) Δ −77.79 (MTW)	A chem, genet (DosI63a, CareA52) parent Sr^{85} (DosI63a, CareA52, NiecW65) daughter 1.4 h Zr^{85} (ZaitN65)	β^+ 2.24 max e^- 0.215 γ Sr X-rays, 0.231 (13%), 0.511 (140%, $\gamma^{\pm}$), 0.77 (8%), 2.16 (9%) daughter radiations from Sr^{85}	Sr^{84}(d, n) (DosI63a)
Y^{85m}	2.68 h (DosI63a) 2.5 h (NiecW65) others (MaxV62, PatA62a, ButeF63)	☢ β^+ 55%, EC 45%, no IT, lim 1% (DosI63a) Δ −77.75 (LHP, MTW)	A chem, genet (MaxV62, DosI63a) parent Sr^{85m} (MaxV62, DosI63a, NiecW65) daughter Zr^{85} (ButeF63, DosI63a, ZaitN65)	β^+ 1.54 max γ Sr X-rays, 0.51 (200%, complex, includes $\gamma^{\pm}$), 0.92 (9%) daughter radiations from Sr^{85m} Sr^{85}	Sr^{84}(d, n) (DosI63a) Sr^{84}(p, γ) (PatA62a)
Y^{86}	14.6 h (HydE51, CastS51, ButeF63)	☢ [EC 74%, β^+ 26%] (VNooB65) [EC 72%, β^+ 28%] (YamaT62a) Δ −79.23 (MTW)	A chem, excit, sep isotopes (CastS51) genet energy levels (VNooB65, HarpJ63) daughter Zr^{86} (HydE51) daughter Y^{86m} (HasL61, KimY62)	β^+ 3.15 max (0.5%), 2.34 max γ Sr X-rays, 0.443 (14%), 0.511 (35%, doublet, includes $\gamma^{\pm}$), 0.63 (37%, doublet), 0.704 (14%), 0.778 (21%), 0.836 (7%), 1.026 (10%), 1.077 (82%), 1.16 (35%, doublet), 1.857 (18%), 1.925 (24%)	Rb^{85}(α, 3n) (YamaT62a) Sr^{86}(p, n) (VNooB65, YamaT62a) Sr^{88}(p, 3n) (CastS51)
Y^{86m}	48 m (KimY62) 49 m (HasL61)	☢ IT (HasL61) Δ −79.01 (LHP, MTW)	A chem, cross bomb, genet (HasL61) chem, cross bomb, sep isotopes, genet (KimY62) parent Y^{86} (HasL61, KimY62)	γ Y L X-rays, 0.208 (94%) e^- 0.008 daughter radiations from Y^{86}	Rb^{85}(α, 3n) (HasL61, KimY62)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{39}Y^{87}$	80 h (MannL51, HydE51, DubL40)	☢ EC 99+%, β^+ ≈0.3% (MannL51) Δ −83.2 (MTW)	A chem (StewD37) chem, excit, cross bomb (DubL40) daughter Y^{87m} (MannL50, MannL51, HydE51) parent Sr^{87m} (DubL40, DubL39, LindnM50a, MannL50, HydE51, MannL51)	β^+ 0.7 max (?) γ Sr X-rays, 0.483 daughter radiations from Sr^{87m}	Sr^{86}(d, n) (StewD37, DubL40, MannL51, MannL50) Sr^{87}(p, n) (DubL40, MannL51)
Y^{87m}	14 h (DubL40, HydE51, MannL51) 13 h (VanR65)	☢ IT (DubL40) β^+ ≈5% (YamaT62a) no β^+ (HydE51) Δ −82.8 (LHP, MTW)	A chem (StewD37) chem, excit, cross bomb (DubL40) daughter Zr^{87} (HydE51) parent Y^{87} (MannL50, HydE51, MannL51)	β^+ 1.60 max (?) e^- 0.364, 0.379 γ Y X-rays, 0.381 (74%) daughter radiations from Y^{87}	Sr^{86}(d, n) (StewD37, DubL40, MannL50, MannL51) Y^{89}(p, 3n) Zr^{87}(β^-) (ButeF63, AwaY64)
Y^{88}	108.1 d (WyaE61) 105 d (DubL40)	☢ EC 99+%, β^+ 0.20% (RhoJ63) Δ −84.27 (MTW)	A chem (DubL40) chem, excit (HelmhA42) mass spect (HaydR48) daughter Zr^{88} (HydE51)	β^+ 0.76 max γ Sr X-rays, 0.898 (91%), 1.836 (100%)	Sr^{88}(p, n) (DubL40) Sr^{88}(d, 2n) (PecC40, HelmhA42, GamG44, BradE50)
$\underline{Y^{89}}$		% 100 (DempA39, CollT57) Δ −87.678 (MTW) σ_c 1.3 (to Y^{90}) 0.001 (to Y^{90m}) (GoldmDT64)			
Y^{89m}	16.1 s (SwanC55) 16.5 s (SatA62) 16.8 s (BroaK65) 16 s (BramE62, BramE63) others (GoldhM51)	☢ IT (GoldhM51) Δ −86.77 (LHP, MTW)	A chem, genet (GoldhM51) daughter Zr^{89} (GoldhM51) daughter Sr^{89} 0.009% (SatA62); 0.02% (LyoW55b), 0.01% (HerrmG56); <0.0005% (BisA55d)	γ 0.91 (99%) e^- 0.89	daughter Zr^{89} (GoldhM51)
Y^{90}	64.0 h (PepD57, HeaR61) 63.7 h (VGunH63) 64.8 h (HerrmG56, MaraE55) 64.2 h (VolH55, SchmP55) 64.3 h (RobeJ59a) 64.6 h (ChetA54) 64.4 h (WriH57) 64.9 h (BiryE61a)	☢ β^- (StewD37) Δ −86.50 (LHP, MTW)	A chem, excit, cross bomb (StewD37) chem, mass spect (HaydR48) daughter Sr^{90} (HahO42, HahO43, GrumW46, NotR51) daughter Y^{90m} (HasL61, AlfWL61)	β^- 2.27 max average β^- energy: 0.93 calorimeter (BiryE61a) 0.90 ion ch (CaswR52) γ no γ	Y^{89}(n, γ) (StewD37, SagR38, SerL47b) daughter Sr^{90} (HahO42, HahO43, GrumW46, NotR51)
Y^{90m}	3.1 h (AlfWL61, LyoW61a, HeaR61) 3.2 h (HasL61, BacM60, CartC61, DavP64) 3.0 h (BramE62) others (FergJ61a)	☢ IT 99.6%, β^- 0.4% (DavP64) Δ −85.81 (LHP, MTW)	A chem, cross bomb, sep isotopes, genet, excit, n-capt (LyoW61a, HasL61, HeaR61, AlfWL61, FergJ61a, CartC61) parent Y^{90} (HasL61, AlfWL61)	γ Y X-rays, 0.202 (97%), 0.482 (91%), 2.315 (0.4% with Zr^{90m}) e^- 0.185, 0.465 daughter radiations from Y^{90}	Rb^{87}(α, n) (CartC61, HasL61) Y^{89}(n, γ) (HeaR61, FergJ61a, LyoW61a) Y^{89}(d, p) (CartC61) Nb^{93}(n, α) (BramE62, AlfWL61, LyoW61a)
Y^{91}	58.8 d (HoffD63) 59.1 d (WyaE61) 57.5 d (KahB55) 58.3 d (HerrmG56) others (GrumW46, LangeL49, BolF53, GotH41, HahO40c, JoliF44)	☢ β^- (HahO40c) Δ −86.35 (MTW) σ_c 1.4 (GoldmDT64)	A chem, genet (HahO40c, HahO43) chem, mass spect (BradE51a, HaydR48) daughter Sr^{91} (GotH41, HahO43, FinB51) descendant Kr^{91} (HahO40c, BradE51, DilC51, DilC51a)	β^- 1.545 max γ 1.21 (0.3%)	fission (GotH41, HahO43, FinB51, FinB51c, EngeD51c)
Y^{91m}	50.3 m (AmeD53) 51.0 m (FinB51) 50 m (GotH41)	☢ IT, no β^-, lim 1.5% (AmeD53) Δ −85.80 (LHP, MTW)	A chem, genet (GotH41) daughter Sr^{91} (GotH41, HahO43, FinB51)	γ Y X-rays, 0.551 (95%) e^- 0.534	fission, daughter Sr^{91} (GotH41, HahO43, FinB51)
Y^{92}	3.53 h (FritK60) 3.50 h (BunkM62) 3.5 h (AgeM43, HahO43b, LieC39)	☢ β^- (LieC39) Δ −84.83 (MTW)	A chem (LieC39) fission fragment range (KatcS48) chem, sep isotopes (SchoG53) daughter Sr^{92} (GotH41, HoaE51b) descendant Kr^{92}, descendant Rb^{92} (DilC51a)	β^- 3.63 max γ 0.448 (2.3%), 0.560 (2.6%), 0.934 (14%), 1.40 (4.7%), 1.83 (0.4%)	Zr^{94}(d, α) (SchoG53, CassW55) fission, daughter Sr^{92} (GotH41, HoaE51b, BunkM62, KatcS48) Zr^{92}(n, p) (SagR40a, SeeW43b, AgeM43)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{39}Y^{93}$	10.3 h (KniJD59) 10.1 h (FritK60) others (BallN51a, HahO43)	☢ β^- (BallN51a) Δ −84.22 (MTW, SteinE65)	A chem (HahO43, BallN46, BallN51a, SelB51) fission fragment range (KatcS48) genet (HahO43, HahO43b, KniJD59) daughter Sr^{93} (HahO43, HahO43b, KniJD59) descendant Kr^{93} (SelB51) descendant Rb^{93} (FritK60)	β^- 2.89 max γ 0.267 (6%), 0.67 (0.7%), 0.94 (2.3%), 1.42 (0.7%), 1.90 (1.8%), 2.18 (0.3%, doublet)	fission (HahO43, HahO43b, BallN51a, FritK60, KniJD59)
Y^{94}	20.3 m (FritK61) 20 m (KniJD59, DilC51b, HahO43) 16 m (BrowLJ49)	☢ β^- (HahO43, HahO43b) Δ −82.3 (MTW)	A chem (HahO43, HahO43a) fission fragment range (KatcS48) chem, sep isotopes (SchoG53) daughter Sr^{94} (HahO43, HahO43b, KniJD59) descendant Kr^{94} (HahO43b, DilC51a) descendant Rb^{94} (FritK61, HahO43, HahO43b, DilC51)	β^- 5.0 max γ 0.56 (6%), 0.92 (43%), 1.13 (5%), 1.65 (2.4%), 1.90 (1.6%), 2.13 (2.4%), 2.57 (1.5%, complex), 3.06 (1.3%), 3.53 (1.1%)	fission (HahO43, HahO43b, KatcS48, KniJD59, FritK61, DilC51a) Zr^{96}(d, α) (SchoG53)
Y^{95}	10.9 m (FritK61) 10.5 m (KniJD49)	☢ β^- (KniJD49) Δ −81 (MTW)	B chem, sep isotopes, excit (KniJD49) daughter Sr^{95} (FritK61)	γ 1.30 (?), 1.80 (?)	fission (FritK61, KniJD59) Zr^{96}(γ, p) (KniJD49)
Y^{96}	2.3 m (ValliD61)	☢ β^- (ValliD61) Δ −79 (MTW)	B chem, excit (ValliD61)	β^- 3.5 max γ 0.7, 1.0, 1.5 (complex)	Zr^{96}(n, p) (ValliD61)
$_{40}Zr^{81}$	7–15 m genet (ZaitN65)	☢ [β^+, EC] (ZaitN65)	E chem, genet (ZaitN65) ancestor Sr^{81}, Rb^{81} (ZaitN65)		protons on Y^{89} (ZaitN65)
Zr^{82}	10 m genet (ZaitN65)	☢ [β^+, EC] (ZaitN65)	D chem, genet (ZaitN65) parent Y^{82}, ancestor Sr^{82} (ZaitN65)		protons on Y^{89} (ZaitN65)
Zr^{83}	5–10 m genet (ZaitN65)	☢ [EC, β^+] (ZaitN65)	E chem, genet (ZaitN65) ancestor Sr^{83} (ZaitN65)		protons on Y^{89} (ZaitN65)
Zr^{84}	16 m genet (ZaitN65)	☢ [EC, β^+] (ZaitN65)	B chem, genet (ZaitN65) parent Y^{84} (ZaitN65)		protons on Y^{89} (ZaitN65)
Zr^{85}	15 m (ZaitN65) 6 m (ButeF63)	☢ [EC, β^+] (ButeF63)	B chem, genet (ButeF63, ZaitN65) parent Y^{85m}, ancestor Sr^{85m} (ButeF63, DosI63a, ZaitN65)		Y^{89}(p, 5n) (ButeF63)
Zr^{85}	1.4 h genet (ZaitN65)	☢ [EC, β^+] (ZaitN65)	B chem, genet (ZaitN65) parent Y^{85} (ZaitN65)		protons on Y^{89} (ZaitN65)
Zr^{86}	16.5 h (AwaY64) 17 h genet (HydE51) 15 h genet (ZaitN65)	☢ EC, no β^+, lim 0.1% (HydE66, HydE54a) Δ −78 (MTW)	A chem, genet (HydE51) parent Y^{86} (HydE51)	γ Y X-rays, 0.028 (20%), 0.243 (96%), 0.612 (5%) e^- [0.015] daughter radiations from Y^{86}	Y^{89}(p, 4n) (AwaY64)
Zr^{87}	1.6 h (HydE51) 1.5 h (ButeF63, HoltzR52, ZaitN65) 2.0 h (RobeB49)	☢ β^+, EC (RobeB49) [β^+ 83%, EC 17%] (NDS) Δ −79.7 (MTW)	A chem, excit, sep isotopes (RobeB49) chem, genet (HydE51) parent Y^{87m} (HydE51)	β^+ 2.10 max γ Y X-rays, 0.511 ($\gamma^\pm$, [166%]), 1.2, 2.2 daughter radiations from Y^{87m}, Y^{87}	Y^{89}(p, 3n) (ButeF63, AwaY64)
Zr^{88}	85 d (HydE53a)	☢ EC (HydE51) no β^+ (HydE55) Δ −84 (MTW)	B chem, genet (HydE51) parent Y^{88} (HydE51) descendant Mo^{88} (ButeF64c)	γ Y X-rays, 0.394 (97%) e^- 0.377 daughter radiations from Y^{88}	protons on Nb (HydE51, HydE55)
Zr^{89}	78.4 h (VPatD64) 79.0 h (HamiJ60) 79.3 h (ShuK51) others (HydE51, KatzL53, DubL40, ShoF53, HowD62)	☢ EC 78%, β^+ 22% (VPatD64, MonaS61) Δ −84.85 (MTW)	A chem excit (SagR38, DubL40) parent Y^{89m} (GoldhM51) daughter Nb^{89} (DiaR54, MathH55 descendant Mo^{89} (ButeF64c)	β^+ 0.90 max e^- 0.89 (with Y^{89m}) γ Y X-rays, 0.511 (44%, $\gamma^\pm$), 0.91 (99%, with Y^{89m}), 1.71 (1%)	Y^{89}(p, n) (DubL40, VPatD64) Y^{89}(d, 2n) (GoldhM51, HamiJ60, MonaS61)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{40}Zr^{89m}$	4.18 m (VPatD64) 4.4 m (ShoF53, ShoF51, MangS63) 4.3 m (KatzL53) 4.5 m (DubL40)	☢ IT 94%, EC 4.7%, β^+ 1.4% (VPatD64) IT 93%, EC 5.6%, β^+ 1.8% (ShoF53) Δ -84.26 (LHP, MTW)	A chem, excit (DubL40) daughter Nb^{89m} (DiaR54, MathH55)	β^+ 2.40 max (0.2%), 0.89 max (1.2%) e^- 0.570 γ Zr, Y X-rays, 0.588 (87%), 1.51 (6%)	$Y^{89}(p, n)$ (VPatD64, DubL40)
Zr^{90}		% 51.46 (WhiJ48) Δ -88.770 (MTW) σ_c 0.1 (GoldmDT64)			
Zr^{90m}	0.80 s (WagR63) 0.83 s (SchmW63, CamE55) 0.86 s (WhiW62)	☢ IT (CamE55) Δ -86.45 (LHP, MTW)	A excit (CamE55) genet energy levels (SchmW63, BjoS59)	γ Zr X-rays, 0.133 (4%), 2.18 (14%), 2.32 (86%) e^- 0.115, 0.130	$Nb^{93}(p, \alpha)$ (WhiW62) $Zr^{90}(n, n')$ (CamE55, WagR63, SchmW63)
Zr^{91}		% 11.23 (WhiJ48) Δ -87.893 (MTW) σ_c 1 (GoldmDT64)			
Zr^{92}		% 17.11 (WhiJ48) Δ -88.462 (MTW) σ_c 0.2 (GoldmDT64)			
Zr^{93}	1.5×10^6 y sp act (SteinE65)	☢ β^- (SteinE50) Δ -87.11 (SteinE65, MTW) σ_c <4 (GoldmDT64)	A chem (SteinE50) mass spect (GleL53) parent Nb^{93m} (GleL53)	β^- 0.060 max γ no γ daughter radiations from Nb^{93m}	fission (SteinE50)
Zr^{94}		% 17.40 (WhiJ48) Δ -87.267 (MTW) σ_c 0.08 (GoldmDT64)			
Zr^{95}	65.5 d (FlyK65a) 65 d (BradE51a, GrumW46, CorkJ53b) 66 d (GrossA48) 63 d (SagR40a)	☢ β^- (SagR40a) Δ -85.663 (MTW)	A chem (GrossA40, SagR40a) chem, genet (GoldsB51) parent Nb^{95m}, parent Nb^{95} (HudJ49, BradE51a, JacoL51, SteinE51a) descendant Kr^{95}, descendant Rb^{95} (DilC51)	β^- 0.89 max (2%), 0.396 max γ 0.724 (49%), 0.756 (49%) daughter radiations from Nb^{95}, Nb^{95m}	$Zr^{94}(n, \gamma)$ (SagR40a, SerL47b) fission (HudJ49, BradE51a, JacoL51, SteinE51a, FinB51c)
Zr^{96}	$t_{1/2}(\beta^-) > 3.6 \times 10^{17}$ y sp act (AwsM56) $t_{1/2}(\beta\beta) > 5 \times 10^{17}$ y sp act (AwsM56) $t_{1/2}(\beta\beta)\ 6 \times 10^{16}$ y sp act (MCarJ53)	% 2.80 (WhiJ48) Δ -85.430 (MTW) σ_c 0.05 (GoldmDT64)			
Zr^{97}	17.0 h (BurgW50a, MandeC52, GrossA40, KatcS51b, VasiI58)	☢ β^- (GrossA40) Δ -82.93 (MTW)	A chem (GrossA40) chem, n-capt, sep isotopes (BurgW50a, MandeC52) parent Nb^{97m} (BurgW50a)	β^- 1.91 max γ 0.747 (92%, with Nb^{97m}) daughter radiations from Nb^{97}	$Zr^{96}(n, \gamma)$ (BurgW50a, MandeC52, SagR40a, SerL47b) fission (GrossA40, HahO41, KatcS48)
Zr^{98}	1 m (OrtC60)	☢ [β^-] (OrtC60) Δ -82 (MTW)	E chem, genet (OrtC60) [parent <2 m Nb^{98}], not parent 51 m Nb^{98} (OrtC60)		fission (OrtC60)
Zr^{99}	35 s genet (OrtC60)		G chem, genet (OrtC60) activity not observed, $t_{1/2} \leq 1.6$ s genet (TroD63)		fission (OrtC60)
$_{41}Nb^{88}$	14 m (KorR64, HydE65) 21 m (ButeF64b)	☢ β^+ (HydE65), [EC] Δ -77 (MTW)	B chem, genet (KorR64, HydE65, ButeF64b) daughter Mo^{88} (ButeF64c)	β^+ 3.2 max γ 0.076, 0.141, 0.272, 0.399, 0.511 ($\gamma^{\pm}$), 0.671, 1.058, 1.083	$Br^{79}(C^{12}, 3n)$ (KorR64, HydE65)
Nb^{89}	1.9 h (HydE65, DiaR54, MathH55) 2.0 h (ButeF64b)	☢ β^+ (DiaR54), [EC] Δ -81.0 (MTW)	A chem, genet (DiaR54, MathH55) parent Zr^{89} (DiaR54, MathH55)	β^+ 2.9 max γ 0.511 ($\gamma^{\pm}$), 1.626, 3.577, 3.838 daughter radiations from Zr^{89}	C^{12} on Br (MathH55, HydE65) $Y^{89}(\alpha, 4n)$ (MathH55)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{41}Nb^{89m}$	42 m (ButeF64b) ≈48 m (DiaR54)	☢ β^+ (DiaR54), [EC] Δ −80.2 (LHP, MTW)	A chem, genet (DiaR54, MathH55) parent Zr^{89m} (DiaR54, MathH55) daughter Mo^{89} (ButeF64c)	β^+ 3.1 max e^- 0.570 (with Zr^{89m}) γ 0.511 ($\gamma^\pm$), 0.588 (93%, with Zr^{89m}) daughter radiations from Zr^{89}	C^{12} on Br (MathH55) protons on Zr (DiaR54)
Nb^{90}	14.6 h (OngP54a, ShelR57a) 14.7 h (DiaR53, ButeF64b) others (KunD49, JacoL51)	☢ β^+, EC (BjoS59, LazN58, ShelR57a) EC(K) ≈50% (KuzM57) Δ −82.66 (MTW)	A chem, excit, cross bomb (JacoL51) chem, sep isotopes, cross bomb (KunD49) descendant Mo^{90} (DiaR53, MathH55b)	β^+ 1.50 max e^- 0.115, 0.123 γ Zr X-rays, 0.142 (75%), 0.511 ($\gamma^\pm$), 1.14 (97%), 2.18 (14%), 2.32 (82%) daughter radiations from Zr^{90m} included in above listing	Zr^{90}(p, n) (BjoS59, LazN58) Zr^{90}(d, 2n) (KunD49, JacoL51) descendant Mo^{90} (ButeF64b, DiaR53)
Nb^{90m}	24 s (MathH55b)	☢ IT (MathH55b) Δ −82.54 (LHP, MTW)	A chem, genet (MathH55b) daughter Mo^{90} (MathH55b)	γ Nb X-rays, 0.122 (71%) e^- 0.104, 0.120	daughter Mo^{90} (MathH55b)
Nb^{91}	long (OvaJ51)	☢ [EC] (OvaJ51) Δ −86.8 (MTW)	B genet (OvaJ51) [daughter Nb^{91m}] (OvaJ51)	γ [Zr X-rays]	Zr^{90}(d, n) (OvaJ51)
Nb^{91m}	64 d (BoydG49) 60 d (JacoL51)	☢ IT 97%, EC 3% (NDS) Δ −86.6 (LHP, MTW)	A chem, excit (JacoL51) chem, sep isotopes (OvaJ51)	γ Nb X-rays, 0.104 (0.5%), 1.21 (3%) e^- 0.066, 0.102	Y^{89}(α, 2n) (HaywR55a) Zr^{90}(d, n) (OvaJ51, HaywR55a, JacoL51)
Nb^{92}	>350 y or <1 h (BunkM62)	Δ −86.45 (ShelR64, MTW)	F levels observed in Nb^{93}(d, t) reaction (ShelR64) and in Nb^{93}(p, d) reaction (SweR64)		
Nb^{92m}	10.16 d (BunkM62) 10.15 d (WestH59) others (GlagV61, MacD48, SagR40b, SagR38a)	☢ EC 99+%, β^+ 0.06% (WestH59, BunkM62) no β^-, lim 0.05% (PreiP51) Δ −86.32 (ShelR64, MTW)	A chem, excit (SagR38a)	γ Zr X-rays, 0.934 (99%)	Y^{89}(α, n) (BunkM62)
Nb^{92}	13 h (JameR54)		G chem, excit (JameR54) activity not observed (SilE58, BramE62, BunkM62, BosH64b)		protons on Nb^{93} (JameR54)
Nb^{93}		% 100 (SamM36a, WhiF56) Δ −87.204 (MTW) σ_c 0.1 (to Nb^{94}) 1 (to Nb^{94m}) (GoldmDT64)			
Nb^{93m}	13.6 y (FlyK65a) ≈4 y (SchumR54)	☢ IT (SchumR54) Δ −87.173 (LHP, MTW)	A chem, genet (GleL53) daughter Zr^{93} (85%) (GleL53) daughter Mo^{93} (HohK64)	γ Nb X-rays e^- 0.011, 0.028	daughter Zr^{93} (GleL53) Nb^{93}(n, n') (SchumR54, HohK64)
Nb^{94}	2.0 x 10^4 y sp act, mass spect (SchumR59a) 1.8 x 10^4 y sp act (RolM55) 2.2 x 10^4 y sp act (DouDL53)	☢ β^-, no EC (DouDL53) no EC(K), lim 6% (SchumR59a) Δ −86.35 (MTW) σ_c ≈15 (GoldmDT64)	A n-capt (GoldhM46a) chem, n-capt (HeiR52)	β^- 0.49 max γ 0.702 (100%), 0.871 (100%)	Nb^{93}(n, γ) (GoldhM46a, HeiR52)
Nb^{94m}	6.29 m (KilP62) 6.6 m (SagR40b)	☢ IT 99+%, β^- 0.2% (ReicC63, YinL62) IT 99+%, β^- 0.5% (KilP62) Δ −86.31 (LHP, MTW)	A n-capt, excit (PoolM37, SagR38a, GoldhM48a, KunD46)	γ Nb X-rays, 0.871 (0.2%) e^- 0.023, 0.039	Nb^{93}(n, γ) (PoolM37, SagR38a, SagR40b, SerL47b)
Nb^{95}	35.0 d (WyaE61) 35.6 d (PierA59) 35 d (CorkJ53a, EngeD51) others (JacoL51, LangeL63, FlyK65a)	☢ β^- (GoldsB51) Δ −86.784 (MTW) σ_c ≈7 (GoldmDT64)	A chem (GoldsB46, GoldsB51) chem, excit, cross bomb (JacoL51) daughter Zr^{95} (HudJ49, BradE51a, SteinE51a, JacoL51) daughter Nb^{95m} (SteinE51a, LeviJ51a)	β^- 0.160 max γ 0.765 (100%)	daughter Zr^{95} (HudJ49, BradE51a, JacoL51, SteinE51b)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{41}$Nb^{95m}	90 h (SteinE51a, HudJ49, DrabG55) 84 h (SlaH52a, SlaH53)	☢ IT (SteinE51a) Δ -86.549 (LHP, MTW)	A chem (EngeD46, EngeD51a) chem, genet (SteinE51a) daughter Zr^{95} (HudJ49, BradE51a, JacoL51, SteinE51a) parent Nb^{95} (SteinE51a, LeviJ51a)	γ Nb X-rays, [0.235] e^- 0.216 daughter radiations from Nb^{95}	daughter Zr^{95} (HudJ49, BradE51a, JacoL51, SteinE51a) Mo^{97}(d, α) (JacoL51, BoydG49) Zr^{94}(d, n) (JacoL51)
Nb^{96}	23.35 h (KunD49) 23.5 h (MonaS62)	☢ β^- (KunD49) Δ -85.64 (MTW)	A chem, excit, sep isotopes (KunD49)	β^- 0.7 max γ 0.459 (28%), 0.569 (59%), 0.778 (97%), 0.811 (14%), 0.851 (22%), 1.092 (49%), 1.200 (21%)	Zr^{96}(p, n) (KunD49) Mo^{98}(d, α) (BornP63c)
Nb^{97}	72 m (MandeC52) 74 m (BurgW50a) 75 m (GrossA40)	☢ β^- (GrossA40) Δ -85.61 (MTW)	A chem, genet (GrossA40) daughter Nb^{97m} (SaraB55a)	β^- 1.27 max γ 0.665 (98%)	descendant Zr^{97} (GrossA40, BurgW50a)
Nb^{97m}	1.0 m (BurgW50a)	☢ IT (BurgW50a) Δ -84.86 (LHP, MTW)	A chem, excit, sep isotopes, genet (BurgW50a) daughter Zr^{97} (BurgW50a) parent Nb^{97} (SaraB55a)	γ 0.747 (98%) e^- 0.728 daughter radiations from Nb^{97}	daughter Zr^{97} (BurgW50a)
Nb^{98}	51 m (OrtC60, WahA62, TakaK61) others (BoydG49)	☢ β^- (BoydG49) Δ -83.5 (OrtC60, MTW)	B chem, sep isotopes (BoydG49) chem, genet energy levels (OrtC60) not daughter Zr^{98} (OrtC60)	β^- 3.1 max γ 0.330 (9%), 0.720 (75%), 0.787 (100%), 1.16 (30%), 1.44 (10%), 1.52 (4%), 1.68 (10%), 1.88 (4%), 1.93 (8%)	Mo^{98}(n, p) (OrtC60, TakaK61, WahA62)
Nb^{98}	<2 m (OrtC60)	☢ β^- (OrtC60)	F genet, excit (OrtC60) [daughter Zr^{98}] (OrtC60)	β^- high-energy β	fission, daughter Zr^{98} (OrtC60)
Nb^{99}	2.4 m (OrtC60) 2.3 m (TroD63) 2.5 m (DufR50)	☢ β^- (DufR50) Δ -83 (MTW)	A chem, excit, sep isotopes (DufR50) chem, genet (OrtC60) parent Mo^{99} (OrtC60)	β^- 3.2 max γ 0.100 (↑ 1), 0.260 (↑ 1)	fission (OrtC60, TroD63) Mo^{100}(γ, p) (DufR50)
Nb^{99}	10 s genet (TroD63)	☢ β^- >52% (TroD63)	C chem, genet (TroD63) parent Mo^{99} (TroD63)		fission (TroD63)
Nb^{100}	3.0 m (OrtC60)	☢ [β^-] (OrtC60) Δ -80 (MTW)	B chem, genet energy levels (OrtC60)	γ 0.140 (↑ 10), 0.36 (↑ 55), 0.45 (↑ 40), 0.53 (↑ 100, complex), 0.65, 2.2, 2.3, 2.65, 2.85	fission (OrtC60)
Nb^{100}	11 m (TakaK61)	☢ β^- (TakaK61) Δ -80 (MTW)	C chem, genet energy levels (TakaK61)	β^- 4.2 max (≤10%), 3.5 max γ 0.535 (↑ 100), 0.62 (↑ 60), 1.04 (↑ 10), 1.15 (↑ 10), 1.47 (↑ 5)	Mo^{100}(n, p) (TakaK61)
Nb^{101}	1.0 m genet (OrtC60)	☢ [β^-] (OrtC60)	B chem, genet (OrtC60) parent Mo^{101} (OrtC60)		fission (OrtC60)
$_{42}$Mo^{88}	27 m (ButeF64c)	☢ β^+ (ButeF64c), [EC]	B chem, genet (ButeF64c) parent Nb^{88}, ancestor Zr^{88} (ButeF64c)	β^+ 2.5 max γ 0.511 ($\gamma^{\pm}$), 2.69 daughter radiations from Nb^{88}	protons on Nb, Mo (ButeF64c)
Mo^{89}	7 m (ButeF64c)	☢ β^+ (ButeF64c), [EC]	B chem, genet (ButeF64c) parent Nb^{89m}, ancestor Zr^{89} (ButeF64c)	β^+ 4.9 max γ 0.511 ($\gamma^{\pm}$) daughter radiations from Nb^{89m}	protons on Mo (ButeF64c)
Mo^{90}	5.67 h (PettH66) 5.7 h (DiaR53) 6.3 h (KuzM57) others (KurcB55)	☢ EC 75%, β^+ 25% (CoopJ65) Δ -80.17 (PettH66, MTW)	A chem, genet (DiaR53, MathH55b) ancestor Nb^{90} (DiaR53, MathH55b) parent Nb^{90m} (MathH55b)	β^+ 1.2 max e^- 0.104, 0.120, 0.239, 0.255 γ Nb X-rays, 0.122 (71%), 0.257 (85%), 0.445 (9%), 0.511 (50%, $\gamma^{\pm}$), 0.945 (10%), 1.273 (8%), 1.389 (4%), 1.46 (4%, doublet) daughter radiations from Nb^{90} (daughter radiations from Nb^{90m} included in above listing)	Nb^{93}(p, 4n) (DiaR53, MathH55b, CoopJ65) Zr^{90}(α, 4n) (CoopJ65)

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$_{42}$Mo^{91}	15.49 m (EbrT65) 15.5 m (DufR49b, WafH48, KatzL53) others (AxeP55, BotW39, SagR38)	☢ β$^+$ (SagR38), [EC] Δ −82.3 (MTW)	A excit (BotW37) chem, excit (SagR38) chem, sep isotopes, excit (KunD49a, DufR49b)	β$^+$ 3.44 γ Nb X-rays, 0.511 (γ$^{\pm}$)	Mo^{92}(n, 2n) (KunD49a, HeyF37, SagR38, SagR40a, BrolJ52, EbrT65)
Mo^{91m}	64 s (PrenJ57) 66 s (KatzL53, AxeP55) 73 s (WafH48) 75 s (DufR49b)	☢ IT ≈57%, β$^+$ + EC ≈43% (SmiF56) IT ≈70%, β$^+$ + EC ≈30% (AxeP55) Δ −81.6 (LHP, MTW)	B chem, sep isotopes (DufR49b)	β$^+$ 3.99 max (↑ 15), 2.78 max (↑ 100) e$^-$ 0.638 γ Nb X-rays, Mo X-rays, 0.511 (γ$^{\pm}$, [76%]), 0.658 (54%), 1.21 (27%), 1.53 (15%) daughter radiations from Mo^{91}	Mo^{92}(γ, n) (DufR49b)
Mo^{92}	t$_{1/2}$ (ECEC) >4 x 10^{18} y (WintR55)	% 15.86 (WilliD46) Δ −86.804 (MTW) σ$_c$ <0.3 (to Mo^{93}) <0.006 (to Mo^{93m}) (GoldmDT64)			
Mo^{93}	>100 y genet (HohK64)	☢ EC (BoydG49a) Δ −86.79 (MTW)	A chem, n-capt (BoydG49a) genet (HohK64) parent Nb^{93m} (85%) (HohK64)	γ Nb X-rays daughter radiations from Nb^{93m}	Mo^{92}(n, γ) (BoydG49a) Nb^{93}(p, n) (HohK64)
Mo^{93m}	6.95 h (BoydG52b) 6.75 h (KunD50)	☢ IT (KunD50) Δ −84.36 (LHP, MTW)	A chem, excit (KunD46) chem, excit, cross bomb, sep isotopes (KunD50) chem, excit (BoydG52b) chem, mass spect (AlbuD53, BernaR53) not daughter Tc^{93} (BoydG50)	γ Mo X-rays, 0.264 (58%), 0.685 (100%), 1.479 (100%) e$^-$ 0.244, 0.261	Nb^{93}(d, 2n) (AlbuD53, KunD46, WieM46, KunD50a) Zr^{90}(α, n) (KunD50) Nb^{93}(p, n) (BoydG52b, ForC53)
Mo^{94}		% 9.12 (WilliD46) Δ −88.407 (MTW)			
Mo^{95}		% 15.70 (WilliD46) Δ −87.709 (MTW) σ$_c$ 14 (GoldmDT64)			
Mo^{96}		% 16.50 (WilliD46) Δ −88.794 (MTW) σ$_c$ 1 (GoldmDT64)			
Mo^{97}		% 9.45 (WilliD46) Δ −87.539 (MTW) σ$_c$ 2 (GoldmDT64)			
Mo^{98}		% 23.75 (WilliD46) Δ −88.110 (MTW) σ$_c$ 0.51 (GoldmDT64)			
Mo^{99}	66.7 h (CrowP65) 66.0 h (GunS57) 67.0 h (WriH57) others (SeaG39, CorkJ49a, VasiI58, WafH48, SagR40a)	☢ β$^-$ (SagR38) Δ −85.96 (MTW)	A chem, n-capt, excit (SagR38, SagR40a) parent Tc^{99m} (SeaG39, SagR40a, MedH49, GleL51d, MihJ51) daughter 2.4 m Nb^{99} (OrtC60) daughter 10 s Nb^{99} (TroD63) ancestor Tc^{99} (MotE47a)	β$^-$ 1.23 max γ Tc X-rays, 0.041 (2%), 0.181 (7%), 0.372 (1%), 0.740 (12%), 0.780 (4%) daughter radiations from Tc^{99m}	Mo^{98}(n, γ) (SagR40, SagR40a, MauW41, SerL47b, HumV51) fission (HahO39b, SagR40a, KatcS51c, KatcS48, FinB51c)
Mo^{100}	t$_{1/2}$ (ββ) ≥3 x 10^{17} y sp act (WintR55) others (FremJ52)	% 9.62 (WilliD46) Δ −86.185 (MTW) σ$_c$ 0.2 (GoldmDT64)			
Mo^{101}	14.6 m (MauW41, WilcDR54, OKelG57)	☢ β$^-$ (SagR40a) Δ −83.50 (MTW)	A chem, n-capt (SagR40a) parent Tc^{101} (SagR40, BotW41, HahO41a, HahO41b, MauW41) daughter Nb^{101} (OrtC60)	2.23 max e$^-$ 0.170 γ 0.191 (25%), 0.51 (15%), 0.59 (21%), 0.70 (11%), 0.89 (15%), 1.02 (25%), 1.18 (11%), 1.38 (9%), 1.56 (11%), 2.08 (16%) daughter radiations from Tc^{101}	Mo^{100}(n, γ) (SagR40, SagR40b, MauW41, SerL47b, HumV51)

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${}_{42}\mathrm{Mo}^{102}$	11.5 m (FleJ54) 11.0 m (WileDR54a) 12 m (HahO41a)	☢ β^- (HahO41a) Δ −84 (MTW)	D chem (HahO41a) parent 5 s Tc^{102} (HahO41a, HahO41b, FleJ54)	β^- 1.2 max daughter radiations from 5 s Tc^{102}	fission (HahO41a, FleJ54, WileDR54a)
Mo^{103}	[illegible]2 s genet (VBaeA65) 70 s (KieP63a)	☢ [β^-] (KieP63a)	B chem, genet (KieP63a) parent Tc^{103} (KieP63a)		fission (KieP63a, VBaeA65)
Mo^{104}	1.1 m (KieP62) 1.6 m (TerG64)	☢ β^- (TerG64)	B chem, genet (KieP62) chem, excit (TerG64) parent Tc^{104} (KieP62)	β^- 4.8 max γ 0.070 daughter radiations from Tc^{104}	fission (TerG64, KieP62)
Mo^{105}	40 s (KieP62a) 42 s genet (VBaeA65) others (FleJ55a, FleJ56a, SeeW47)	☢ β^- (BornH43b)	B chem, genet (BornH43b, KieP62a) ancestor Ru^{105} (BornH43b, KieP62a) parent Tc^{105}, ancestor Rh^{105} (KieP62a, BornH43b, FleJ55a)		fission (BornH43b, FleJ55a, FleJ56a, KieP62a, VBaeA65)
${}_{43}\mathrm{Tc}^{92}$	4.4 m (VLieR64)	☢ β^+ ≈92%, EC ≈8% (VLieR64) Δ −78.8 (MTW)	B chem, sep isotopes (MotE48, VLieR64)	β^+ 4.1 max γ Mo X-rays, 0.090 (20%), 0.14 (67%), 0.24 (30%), 0.33 (90%), 0.511 (184%, γ^*), 0.79 (95%), 1.54 (100%)	Mo^{92}(d, 2n) (MotE48, VLieR64)
Tc^{93}	2.75 h (KunD48a) 2.7 h (VinG62, MotE48, DelL39)	☢ EC 87%, β^+ 13% (VinG62, LeviC54a) Δ −83.60 (MTW)	A chem (SeaG39) chem, excit, sep isotopes (KunD48a) not parent Mo^{93m} (BoydG50)	β^+ 0.80 max γ Mo X-rays, 0.511 (26%, γ^*), 1.35 (65%), 1.49 (33%)	Mo^{92}(d, n) (KunD48a, MotE48, SeaG39, VinG62) Mo^{92}(p, γ) (KunD48a, DelL39)
Tc^{93m}	43 m (MedH50, VinG62) 47 m (KunD48a)	☢ IT 82%, EC 18% (VinG62) Δ −83.21 (LHP, MTW)	A chem, excit, sep isotopes (KunD48a) mass spect (BernaR54) chem, mass spect (LeviC54a)	γ Tc X-rays, Mo X-rays, 0.390 (65%), 2.66 (18%) e^- 0.36[illegible] daughter radiations from Tc^{93}	Mo^{92}(d, n) (EasH53, BernaR54, VinG62) Mo^{92}(p, γ) (EasH53) Nb^{93}(α, 4n) (EasH53)
Tc^{94}	293 m (MatuJ63) 270 m (MonaS62a)	☢ EC 89%, β^+ 11% (HamiJ64) EC 93%, β^+ 7% (MatuJ63) EC 86%, β^+ 14% (MonaS62a) Δ −84.15 (MTW)	A excit (MonaS62) chem, excit, cross bomb (MatuJ63)	β^+ 0.816 max γ Mo X-rays, 0.511 (22%, γ^*), 0.702 (100%), 0.849 (100%), 0.871 (100%)	Nb^{93}(α, 3n) (MatuJ63) Mo^{94}(d, 2n) (MatuJ63, MonaS62a, HamiJ64)
Tc^{94m}	53 m (MedH50, MonaS62) 50 m (MotE48a)	☢ β^+ 66%, EC 34% (HamiJ64) β^+ 72%, EC 28% (MonaS62a) β^+ 61%, EC 39% (MatuJ63) Δ −84.04 (LHP, MTW)	A chem, excit (GugP47) chem, excit, sep isotopes (MotE48a) genet energy levels (HamiJ64) daughter Ru^{94} (VWieA52)	β^+ 2.47 max γ Mo X-rays, 0.511 (132%, $\gamma^{\pm}$), 0.871 (91%), 1.53 (10%), 1.87 (9%), 2.73 (5%), 3.20 (2%)	Nb^{93}(α, 3n) (MatuJ63) Mo^{94}(d, 2n) (MotE48a, MonaS62, MatuJ63, HamiJ64) Mo^{94}(p, n) (GugP47, HubeO48a, MedH50)
Tc^{95}	20.0 h (VinG62, EggD48) 20 h (MotE48a)	☢ EC (EggD48) no β^+ (MedH50) Δ −86.05 (MTW)	A chem, sep isotopes (EggD48, MotE48a)	γ Mo X-rays, 0.768 (82%), 0.84 (11%), 1.06 (4%)	Mo^{95}(p, n) (EggD48, MedH50) Mo^{94}(d, n) (VinG62) Mo^{95}(d, 2n) (MotE48a)
Tc^{95m}	61 d (UniJ59) 60 d (MedH50) 62 d (CacB39) 52 d (EdwJ47)	☢ EC 95%, β^+ 0.42%, IT 4% (UniJ59, MedH50, MedH50a, CreT65a) Δ −86.01 (LHP, MTW)	A chem (CacB37, CacB39) chem, sep isotopes (MotE48b)	β^+ 0.68 max e^- 0.019, 0.036, 0.184 γ Mo X-rays, 0.204 (70%), 0.584 (36%), 0.78 (12%, complex), 0.823 (9%), 0.838 (27%), 1.042 (4%) daughter radiations from Tc^{95}	Mo^{95}(p, n) (EdwJ47) Mo^{94}(d, n) (CacB37, CacB39, UniJ59) Mo^{95}(d, 2n) (MotE48b)
Tc^{96}	4.35 d (MedH50) 4.20 d (CobJ50) 4.3 d (MonaS62, EdwJ47) 4.2 d (MotE48b)	☢ EC (MotE48b) no β^+ (MedH50) Δ −85.9 (MTW)	A chem (EwiD39) chem, excit, cross bomb (EdwJ47) chem, excit, sep isotopes (MedH52)	γ Mo X-rays, 0.32 (5%), 0.778 (100%), 0.81 (84%), 0.851 (100%), 1.12 (16%) e^- 0.30, 0.75, 0.79, 0.82	Nb^{93}(α, n) (EdwJ47)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{43}$Tc^{96m}	52m (MedH50, EasH53)	☢ IT (MedH50) β^+ ≈0.01% (EasH53) Δ −85.8 (LHP, MTW)	B chem, excit (MedH50) chem, excit, sep isotopes (MedH52)	γ Tc X-rays e^- 0.013, 0.032 daughter radiations from Tc^{96}	Nb^{93}(α, n) (EasH53)
Tc^{97}	2.6 x 10^6 y yield (KatcS58a) others (BoydG54)	☢ EC (BoydG54) Δ −87 (MTW)	A genet (BoydG51a) chem (KatcS58a) [daughter Tc^{97m}] (BoydG51a) daughter Ru^{97} (99+%) (KatcS58a)	γ Mo X-rays	Ru^{96}(n, γ)Ru^{97}(β^-) (KatcS58a) Mo^{97}(d, 2n) (BoydG54)
Tc^{97m}	91 d (BoydG54, HelmhA41a) 90 d (MotE48b, GugP47, CacB37) 87 d (UniJ59) 95 d (EdwJ47)	☢ IT (HelmhA41a, EdwJ47) Δ −87 (LHP, MTW)	A chem (PerrC37, CacB37) chem, genet (MotE47) excit, sep isotopes (MotE48b) daughter Ru^{97} (0.04%) (KatcS58a)	γ Tc X-rays e^- 0.075, 0.094	Mo^{96}(d, n) (CacB37, PerrC37, CacB39) Mo^{97}(p, n) (EdwJ47) Mo^{97}(d, 2n) (MotE48b) Ru^{96}(n, γ)Ru^{97}(β^-) (KatcS58a)
Tc^{98}	1.5 x 10^6 y sp act (OKelG56b) others (KatcS55)	☢ β^- (KatcS55) Δ −86.5 (MTW) σ_c 3 (to Tc^{99m}) (GoldmDT64)	A chem, mass spect (BoydG55)	β^- 0.30 max γ 0.66 (100%), 0.76 (100%)	Mo^{98}(p, n) (BoydG55) Ru^{96}(n, γ)Ru^{97}(β^-) Tc^{97}(n, γ) (KatcS55, KatcS58a)
Tc^{99}	2.12 x 10^5 y sp act (FrieS51) 2.15 x 10^5 y sp act (BoydG60)	☢ β^- (LincD51, SchumR51) Δ −87.33 (MTW) σ_c 22 (GoldmDT64)	A chem (LincD46, SchumR46) chem, mass spect (IngM47g) daughter Tc^{99m} (SeaG39, HahO41a) descendant Mo^{99} (MotE47a)	β^- 0.292 max γ no γ	fission (IngM47g, LincD51, SchumR51) Mo^{98}(n, γ)Mo^{99}(β^-) (MotE47a)
Tc^{99m}	6.049 h (GleG64) 6.00 h (ByeD58) others (GleL51d, BaiK53, PortR60, CreT65)	☢ IT (SeaG39) Δ −87.18 (LHP, MTW)	A chem, genet (SeaG39) daughter Mo^{99} (SeaG39, SagR40a, MedH49, GleL51d, MihJ51) parent Tc^{99} (SeaG39, HahO41a)	γ Tc X-rays, 0.140 (90%) e^- 0.001, 0.119	daughter Mo^{99} (SeaG39, SagR40a, MedH49, GleL51d, MihJ51)
Tc^{100}	15.8 s (BoydG52a) 17.5 s (HouR52) 17 s (CsiG63)	☢ β^- (HouR52) Δ −85.9 (MTW)	A sep isotopes (HouR52) sep isotopes, n-capt (BoydG52a)	β^- 3.38 max γ 0.540 (strong), 0.60 (strong), 0.71, 0.81, 0.89, 1.01, 1.31, 1.49, 1.8	Tc^{99}(n, γ) (BoydG52a, OKelG58) Mo^{100}(p, n) (HouR52) Rh^{103}(n, α) (CsiG63)
Tc^{101}	14.0 m (OKelG57, MauW41, HahO41b) 14.3 m (WileDR54) 14.5 m (PerlmM48) 16.5 m (MacD48)	☢ β^- (SagR40) Δ −86.32 (MTW)	A chem, genet (SagR40) daughter Mo^{101} (BotW41, HahO41a, HahO41b, MauW41, SagR40)	β^- 1.32 max γ 0.13 (3%, complex), 0.307 (γ 91%), 0.545 (γ 8%)	Mo^{100}(n, γ)Mo^{101}(β^-) (SagR40, SagR40b, MauW41)
Tc^{102}	4.5 m (FleJ54, FleJ57)	☢ β^- (FleJ56a) Δ −85 (MTW)	[illegible] chem, genet energy levels (FleJ56a, FleJ57)	β^- 2 max γ 0.47	Ru^{102}(n, p) (FleJ57) fission (FleJ56a)
Tc^{102}	5 s (FleJ54) others (HahO41a)	☢ β^- (HahO41a) Δ −85 (MTW)	C chem, genet (HahO41a, FleJ54) daughter Mo^{102} (HahO41a, HahO41b, FleJ54)	β^- 4.4 max	daughter Mo^{102} (HahO41a, HahO41b, FleJ54)
Tc^{103}	50 s (KieP63a, VBaeA65) 72 s (FleJ57)	☢ β^- (KieP63b) Δ −84.[illegible] (MTW)	B excit (FleJ57) chem, genet (KieP63a) [parent Ru^{103}] (KieP63a) daughter Mo^{103} (Kie[illegible])	β^- 2.2 max [illegible].135 (I 17), 0.21 (I 10), 0.35	fission (KieP63a, KieP63b, VBaeA65) Ru^{104}(n, np) (FleJ57)
Tc^{104}	18 m (FleJ56a, KieP62)	☢ β^- (FleJ56a, KieP62) Δ −82.2 (MTW)	B chem (FleJ56a) chem, genet energy levels (KieP62) daughter Mo^{104} (KieP62)	β^- [5.8 max] (weak), 4.6 max γ 0.36, 0.53, 0.8[illegible] 1.15, 1.25, 1.37, 1.6 (complex), 1.9, 2.2 2.7, 3.2, 3.4, 3.7, 4.0, 4.4, 4.7	fission (FleJ56a, KieP62) Ru^{104}(n, p) (FleJ57)
Tc^{105}	7.7 m (KieP62a) 7.8 m (VBaeA65) 10 m genet (FleJ55a, FleJ56a)	☢ β^- (BornH43b) Δ −82.6 (MTW)	B chem, genet (BornH43b) parent Ru^{105}, daughter Mo^{105} (BornH43b, FleJ55a, KieP62a) ancestor Rh^{105} (KieP62a)	β^- 3.4 max γ 0.110 daughter radiations from Ru^{105}	fission (BornH43b, FleJ55a, FleJ56a, KieP62a, VBaeA65)

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$_{43}$Tc^{106}	37 s (VBaeA65)	☢ [β^-] (VBaeA65)	B chem, genet (VBaeA65) parent Ru^{106} (VBaeA65)		fission (VBaeA65)
Tc^{107}	29 s (VBaeA65) others (BornH43b)	☢ [β^-] (VBaeA65)	B chem, genet (VBaeA65) ancestor Rh^{107} (VBaeA65)		fission (VBaeA65)
$_{44}$Ru^{93}	50 s (AteA55a)	☢ β^+ (?) (AteA55a)	E chem, excit (AteA55a)		Mo^{92}(α, 3n) (AteA55a)
Ru^{94}	57 m genet (VWieA52)	☢ EC (VWieA52)	D chem, genet (VWieA52) parent Tc^{94m} (VWieA52)	γ [Tc X-rays] daughter radiations from Tc^{94m}	Mo^{92}(α, 2n) (VWieA52)
Ru^{95}	1.65 h (SchaE56, EggD48) 1.7 h (KurcB55) 1.6 h (MocD48)	☢ EC 85%, β^+ 15% (RieP63) Δ -84.02 (MTW)	A chem, cross bomb, sep isotopes (EggD48)	β^+ 1.33 max γ Tc X-rays, 0.340 (70%), 0.511 (30%, $\gamma^{\pm}$), 0.625 (13%), 1.09 (21%), 1.43 (5%) daughter radiations from Tc^{95}	Mo^{92}(α,n) (EggD48) Ru^{96}(n, 2n) (EggD48, SchaE56, RieP63)
Ru^{96}		% 5.46 (OrdK60) 5.57 (WhiF56) 5.50 (FrieL53) 5.7 (EwaH44) Δ -86.07 (MTW) σ_c 0.2 (GoldmDT64)			
Ru^{97}	2.88 d (KatcS58a) 2.8 d (MocD48, SulW46, AteA55b, ShpV56) 2.44 d (CorkJ55a)	☢ EC (SulW46) Δ -86 (MTW)	A chem, excit (SulW46) chem, cross bomb, sep isotopes (EggD48) parent Tc^{97m} (0.04%), parent Tc^{97} (99+%) (KatcS58a) daughter 32 m Rh^{97} (AteA55b)	γ Tc X-rays, 0.215 (91%), 0.324 (8%) e^- 0.194	Ru^{96}(n, γ) (SulW46, KatcS58a, CorkJ55a) Mo^{94}(α, n) (EggD48)
Ru^{98}		% 1.868 (OrdK60) 1.86 (WhiF56) 1.91 (FrieL53) 2.2 (EwaH44) Δ -88.222 (MTW) σ_c <8 (GoldmDT64)			
Ru^{99}		% 12.63 (OrdK60) 12.7 (WhiF56, FrieL53) 12.8 (EwaH44) Δ -87.619 (MTW) σ_c 11 (GoldmDT64)			
Ru^{100}		% 12.53 (OrdK60) 12.7 (FrieL53) 12.6 (WhiF56) Δ -89.219 (MTW) σ_c 10 (GoldmDT64)			
Ru^{101}		% 17.02 (OrdK60) 17.0 (EwaH44, FrieL53) 17.1 (WhiF56) Δ -87.953 (MTW) σ_c 3 (GoldmDT64)			
Ru^{102}		% 31.6 (OrdK60, WhiF56) 31.5 (FrieL53) 31.3 (EwaH44) Δ -89.098 (MTW) σ_c 1.4 (GoldmDT64)			
Ru^{103}	39.5 d (FlyK65a) 39.8 d (KondE50a) 39.4 d (CaliJ59) others (WriH57, SulW51d, BohE45, HoleN48a, GleL51e, MocD48, NisY42)	☢ β^- (NisY42) Δ -87.27 (MTW)	A excit (LivJ36) chem (NisY42, GoldsB46) chem, excit (SulW51d, SulW51f) parent Rh^{103m} (SulW51f) [daughter Tc^{103}] (KieP63a)	β^- 0.70 max (3%), 0.21 max γ 0.497 (88%), 0.610 (6%) daughter radiations from Rh^{103m}	Ru^{102}(n, γ) (SulW51d, DVriH38) fission (NisY41, NisY42, GoldsB51a, SulW51e, FinB51c)

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$_{44}$Ru^{104}		% 18.87 (OrdK60) 18.5 (WhiF56) 18.7 (FrieL53) 18.3 (EwaH44) Δ −88.090 (MTW) σ_c 0.48 (GoldmDT64)			
Ru^{105}	4.44 h (RiccR60) 4.43 h (BranHW62) others (SleN51, SulW51, SulW51b, BohE45, ShpV56)	☢ β^- (NisY41) Δ −86.00 (MTW) σ_c 0.2 (GoldmDT64)	A chem (SegE41) chem, excit (SulW51a) daughter Tc^{105} (BornH43b, FleJ55a, KieP62a) parent Rh^{105m} (DufR51) parent Rh^{105m} (25%) (BranHW62); (27%) (NeesJ65) descendant Mo^{105} (BornH43b, KieP62a) ancestor Rh^{105} (NisY41, BohE45, SleN51, SulW51a)	β^- 1.87 max (11%), 1.15 max γ 0.263 (6%), 0.317 (11%, doublet), 0.40 (6%, doublet), 0.475 (20%, doublet), 0.67 (16%, doublet), 0.726 (48%) daughter radiations from Rh^{105m} Rh^{105}	Ru^{104}(n, γ) (DVriH38, SulW51a)
Ru^{106}	368 d (FlyK65a) 367 d (SchumR56) 366 d (EasH60) 371 d (WyaE61) others (MerW57, GleL51e, SeeW46)	☢ β^- (GoldsB51a, GleL51e) Δ −86.33 (MTW) σ_c 0.15 (GoldmDT64)	A chem (GoldsB46, GleL46a) chem, mass spect (HaydR48) parent 30 s Rh^{106} (SeeW46, GrumW46, GleL51e) not parent 130 m Rh^{106} (BaraG55) daughter Tc^{106} (VBaeA65)	β^- 0.039 max γ no γ daughter radiations from 30 s Rh^{106}	fission (GleL51e, HaydR48, GrumW48, FinB51c)
Ru^{107}	4.2 m (PierW62) 4.8 m (BaumF58) 4 m (GleL51f, BornH43b)	☢ β^- (BornH43b) Δ −83.7 (MTW)	B chem (BornH43b, GleL51f, BaumF58) chem, genet (PierW62) parent Rh^{107} (PierW62, GleL51f, BornH43b, BaroG55a) [daughter Tc^{107}] (BornH43b)	β^- 3.2 max γ 0.195 (14%), 0.37 (weak), 0.48 (weak), 0.86 (7%), 0.93 (4%), 1.03 (4%), 1.29 (4%) daughter radiations from Rh^{107}	Pd^{110}(n, α) (BaumF58, BaroG55a) fission (BornH43b, GleL51f, BaroG55a, BaumF58, PierW62)
Ru^{108}	4.5 m (PierW62) 4.4 m (BaumF58) others (BaroG55a)	☢ β^- (BaroG55a) Δ −84 (MTW)	B chem, excit (BaroG55a) chem, genet (BaumF58, PierW62) parent Rh^{108} (BaumF58, PierW62, BaroG55a)	β^- 1.3 max γ 0.165 (28%) daughter radiations from Rh^{108}	fission (BaroG55a, BaumF58, PierW62)
$_{45}$Rh^{97}	32 m (BasuB62a, EggD49) 37 m (ChikV62) 35 m (AteA55b)	☢ β^+ (AteA52a, [EC] Δ −83 (MTW)	A chem, genet (AteA55b) chem, excit (ChikV62) excit, sep isotopes (BasuB62a) parent Ru^{97} (AteA55b)	β^+ 2.47 max γ Ru X-rays, 0.08, 0.187, 0.255, 0.420, 0.511 ($\gamma^{\pm}$), 0.86, 1.18, 1.57, 1.70, 1.96, 2.16 daughter radiations from Ru^{97}	Ru^{96}(d, n) (AteA55b, AteA52a, ChikV62) Ru^{96}(p, γ) (BasuB62a)
Rh^{97}	1.0 m (BasuB62a)	☢ β^+ ? (BasuB62a)	F sep isotopes (BasuB62a)	γ 0.75	Ru^{96}(p, γ) (BasuB62a)
Rh^{98}	8.7 m (KatcS56a) 9 m (AteA55)	☢ β^+ (AteA52a), [EC] Δ −84.0 (MTW)	B chem, excit (AteA52a, AteA53d, AteA55b) daughter Pd^{98} (AteA55b, KatcS56a)	β^+ 2.5 max γ [Ru X-rays, 0.511 ($\gamma^{\pm}$)], 0.65 (100%)	daughter Pd^{98} (AteA55b, KatcS56a)
Rh^{99}	16.1 d (TownCW59) 15.0 d (FarmD55)	☢ β^+, EC (FarmD55, MatthE65) Δ −85.57 (NDS, MTW)	B chem (FarmD55, HisK56) genet energy levels (TemG56a, MatthE65)	β^+ 1.03 max γ Ru X-rays, 0.090, 0.175, 0.31 (complex), 0.354, 0.444, 0.48 (complex), 0.511 ($\gamma^{\pm}$), 0.529, others to 2.7	Ru^{99}(p, n) (FarmD55, MatthE65)
Rh^{99}	4.7 h (KatcS56a) 4.5 h (ScoC52)	☢ EC 90%, β^+ 10% (KatcS56a) Δ −85.52 (LHP, NDS, MTW)	B chem, excit (EggD49) daughter Pd^{99} (KatcS56a, AteA55b)	β^+ 0.74 max γ Ru X-rays, 0.34 (70%), 0.511 (20%, $\gamma^{\pm}$), 0.62 (20%), 0.89, 1.26, 1.41	Ru^{99}(p, n) (EggD49, ScoC52) Ru^{98}(d, n) (ScoC52, EggD49)
Rh^{100}	20.8 h (MarqL53a) 19.4 h (LindnM48a) 18 h (AntoN64b) 21 h (SulW51k)	☢ EC 93%, β^+ 7% (KoiM64) Δ −85.58 (MTW)	A chem (SulW51k, LindnM48a) excit, sep isotopes (BasuB62) daughter Pd^{100} (LindnM48a)	β^+ 2.62 max e^- 0.516 γ Ru X-rays, 0.444 (8%), 0.511 (13%, $\gamma^{\pm}$), 0.540 (88%), 0.820 (25%), 1.11 (13%), 1.35 (20%), 1.55 (23%), 1.93 (10%), 2.37 (39%), all γ rays complex	daughter Pd^{100} (LindnM48a, KoiM64) Ru^{100}(p, n) (KoiM64) Ru^{99}(d, n) (SulW51e) Ru^{99}(p, γ) (BasuB62)

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$_{45}$Rh^{101}	3.0 y (HisK65) 5 y (FarmD55) 10 y (PerrN60)	☢ [EC] (FarmD55) Δ −87.39 (MTW)	B chem (FarmD55) genet energy levels, excit (SharmB60)	γ [Ru X-rays], 0.127 (88%), 0.198 (75%), 0.325 (11%) e^- 0.105, 0.124, 0.176	Ru^{101}(p, n) (SharmB60, FarmD55, PerrN56)
Rh^{101m}	4.4 d (EvaJS65) 4.7 d (KatcS56a) 4.3 d (FarmD55, LindnM48a) 4.5 d (ScoC52) 5.9 d (SulW51j)	☢ EC 90%, IT 10% (EvaJS65) no β^+ (KatcS56a, LindnM48a) Δ −87.24 (LHP, MTW)	A chem, excit (SulW51j) genet energy levels, excit (SharmB60) daughter Pd^{101} (LindnM48a, EvaJS65)	γ Ru X-rays, Rh X-rays, 0.307 (83%), 0.545 (6%) e^- 0.134, 0.154	Ru^{101}(p, n) (ScoC52, FarmD55, SharmB60) Ru^{100}(d, n) (SulW51j, ScoC52)
Rh^{102}	206 d (HisK61) 210 d (MinaO41) 205 d (MGowF61a) others (HoleN47)	☢ EC, β^+, β^-; β^+/β^- 0.75 (HisK61) 0.84 (MarqL54) Δ −86.77 (MTW)	A chem, excit (MinaO41)	β^- 1.15 max β^+ 1.29 max γ Ru X-rays, 0.475 (57%), 0.511 (25%, $\gamma^\pm$), 0.628 (4%), 1.103 (3%), 1.37 (0.5%), 1.57 (0.2%)	Ru^{102}(p, n) (FarmD55, HisK61, MGowF61a) Ru^{101}(d, n), Ru^{102}(d, 2n) (BesD55, BornP61, SulW51i) Rh^{103}(n, 2n) (MinaO41, HoleN45a)
Rh^{102}	2.9 y (BornP63a) others (MGowF61a, HisK65)	☢ EC (MGowF61a, BornP63a)	B chem, excit (MGowF61a)	γ Ru X-rays, 0.418 (13%), 0.475 (95%), 0.632 (54%, doublet), 0.698 (41%), 0.768 (30%), 1.05 (41%), 1.11 (22%, doublet)	Ru^{102}(p, n) (MGowF61a) deuterons on Ru (BornP63a)
Rh^{103}		% 100 (CohAA43) Δ −88.014 (MTW) σ_c 144 (to Rh^{104}) 11 (to Rh^{104m}) (GoldmDT64)			
Rh^{103m}	57.5 m (JonG56) 57 m (GleL51e) 56 m (MeiJ50a) 45 m (WieM45b) others (FlaA47a, FlaA44)	☢ IT (FlaA44, WieM45b) Δ −87.974 (LHP, MTW)	A chem, excit (FlaA44) chem (GleL46a, GleL51e) chem, genet (SulW51f) daughter Ru^{103} (SulW51f) daughter Pd^{103} (MeiJ50a, BrosA46)	γ Rh X-rays, 0.040 (0.4%) e^- 0.017, 0.037	daughter Ru^{103} (SulW51f) daughter Pd^{103} (MeiJ50a)
Rh^{104}	43 s (CsiJ63) 44 s (AmaE35, PonB38a) 42 s (CriE39)	☢ β^- (PonB38a) EC 0.5% (FrevL65a) no β^+, lim 5×10^{-4}% (LanghH61b) Δ −86.95 (MTW) σ_c 40 (GoldmDT64)	A n-capt (AmaE35) genet (PonB38a) daughter Rh^{104m} (PonB38a, FlaA47a)	β^- 2.44 max γ Ru X-rays, 0.56 (2.0%), 1.24 (0.13%)	daughter Rh^{104m}, Rh^{103}(n, γ) (AmaE35, PoolM37, PoolM38, GrumW46, SerL47b, PonB38a, FlaA47a, HumV51)
Rh^{104m}	4.41 m (ElliJ59) 4.3 m (CsiG63) 4.4 m (CriE39) others (DMatE51, FlaA47a)	☢ IT 99+%, β^- 0.18% (WieK63) Δ −86.82 (LHP, MTW) σ_c 800 (GoldmDT64)	A n-capt (AmaE35) parent Rh^{104} (PonB38a, FlaA47a)	γ Rh X-rays, 0.051 (47%), 0.078 (2.5%), 0.097 (2.6%), 0.56 (0.18%), 0.77 (0.24%, doublet) e^- 0.028, 0.054, 0.074 β^- [0.5 max] daughter radiations from Rh^{104}	Rh^{103}(n, γ) (AmaE35, PoolM37, PonB38a, GrumW46, SerL47b, HumV51)
Rh^{105}	35.88 h (BranHW62) 36.2 h (DufR51) 36.5 h (SulW51a) others (BohE45, NisY41, KunD48, MandeC51)	☢ β^- (NisY41) Δ −87.87 (MTW) σ_c 6,000 (to 30 s Rh^{106}) 15,000 (to 130 m Rh^{106}) (GoldmDT64)	A chem, genet (NisY41, SulW51a) daughter Rh^{105m} (DufR51) descendant Ru^{105} (NisY41, BohE45, SleN51, SulW51a) descendant Tc^{105}, descendant Mo^{105} (KieP62a)	β^- 0.568 max γ 0.306 (5%), 0.319 (19%)	Ru^{104}(n, γ)Ru^{105}(β^-) (SulW51a)
Rh^{105m}	45 s (DufR51)	☢ IT (DufR51) Δ −87.74 (LHP, MTW)	A chem, genet (DufR51) daughter Ru^{105}, parent Rh^{105} (DufR51) daughter Ru^{105} (25%) (BranHW62), (27%) (NeesJ65)	γ Rh X-rays, 0.129 e^- 0.106, 0.126	daughter Ru^{105} (DufR51)
Rh^{106}	30 s (GleL51e) 40 s (SeeW46)	☢ β^- (GleL51e) Δ −86.37 (MTW)	A chem, genet (GleL46a, GleL51e) daughter Ru^{106} (SeeW46, GrumW46, GleL51e)	β^- 3.54 max γ 0.512 (21%), 0.622 (11%, doublet), 1.05 (1.5%, doublet), 1.13 (0.5%, doublet), 1.55 (0.2%)	daughter Ru^{106} (SeeW46, GrumW46, GleL51e)

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$_{45}$Rh^{106}	130 m (MayS58) 133 m (SegO60a) others (BaroG55, NerW55)	☢ β^- (BaroG55) Δ −86.3 (SegO60a, MTW)	A chem, excit (BaroG55, NerW55) genet energy levels (MayS58, SegO60a) not daughter Ru^{106} (BaroG55)	β^- 1.62 max (10%), 1.1 max γ 0.220 (18%, complex), 0.406 (18%), 0.451 (35%), 0.512 (88%), 0.616 (29%), 0.735 (41%), 0.82 (35%), 1.046 (25%), 1.128 (12%), 1.223 (17%), 1.56 (18%)	Pd^{108}(d, α) (BaroG55, MayS58, SegO60a) Ag^{109}(n, α) (MayS58)
Rh^{107}	21.7 m (PierW62) 24 m (BornH43b) 25 m (NerW55) 23.0 m (MallC56, BaroG55a) others (GleL51f)	☢ β^- (BornH43b) Δ −86.86 (MTW)	A chem (BornH43b) chem, sep isotopes, excit (PierW62) daughter Ru^{107} (PierW62, BornH43b, GleL51f, BaroG55a) descendant Tc^{107} (VBaeA65)	β^- 1.20 max γ 0.305 (73%), 0.390 (11%), 0.68 (3%)	Ru^{104}(α, p) (PierW46) fission (BornH43a, GleL51f, PierW62)
Rh^{108}	16.8 s (PierW62) 17.5 s (BaumF58) 18 s (BaroG55a)	☢ β^- (BaroG55a) Δ −85 (MTW)	B chem (BaroG55a) chem, genet energy levels (PierW62) daughter Ru^{108} (BaumF58, PierW62, BaroG55a)	β^- 4.5 max γ 0.434 (43%), 0.51 (10%, complex), 0.62 (22%)	fission, daughter Ru^{108} (BaroG55a, BaumF58, PierW62)
Rh^{109}	<1 h (SeiJ51)	☢ [β^-] (SeiJ51) Δ −85 (MTW)	F genet (SeiJ51) [parent Pd^{109}] (SeiJ51)		fission (SeiJ51)
Rh^{110}	5 s (KarrM63a)	☢ β^- (KarrM63a) Δ −83 (MTW)	C sep isotopes, genet energy levels (KarrM63a)	β^- 5.5 max γ 0.374	Pd^{110}(n, p) (KarrM63a)
$_{46}$Pd^{98}	17.5 m genet (KatcS56a) 17 m genet (AteA53b)	☢ [EC] (AteA53d)	B chem, genet (AteA53d, AteA55b) parent Rh^{98} (KatcS56a, AteA53d)	γ [Rh X-rays], 0.132 (?) daughter radiations from Rh^{98}	Ru^{96}(α, 2n) (AteA55b, KatcS56a)
Pd^{99}	22 m (KatcS56a) 24 m (AteA55b)	☢ β^+ (KatcS56a), [EC] Δ −81.7 (MTW)	B chem, excit (AteA55b, KatcS56a) parent 4.7 h Rh^{99} (KatcS56a, AteA55b)	β^+ 2.0 max γ Rh X-rays, 0.140, 0.275, 0.420, 0.511 ($\gamma^{\pm}$), 0.67 daughter radiations from 4.7 h Rh^{99}	Ru^{96}(α, n) (KatcS56a)
Pd^{100}	4.0 d (LindnM48a) 4.1 d (KurcB55) 3.7 d (AntoN64a)	☢ EC, no β^+ (LindnM48a) Δ −85 (MTW)	A chem, excit, genet (LindnM48a) parent Rh^{100} (LindnM48a)	γ Rh X-rays, 0.074 (34%), 0.084 (49%), 0.126 (16%), 0.159 (4%) e^- 0.010, 0.019, 0.052, 0.061, 0.071, 0.081 daughter radiations from Rh^{100}	Rh^{103}(p, 4n) (KoiM64, EvaJS65a) Rh^{103}(d, 5n) (LindnM48a)
Pd^{101}	8.4 h (EvaJS65) 8.5 h (KatcS56a) others (LindnM50a)	☢ EC 97.5%, β^+ 2.5% (EvaJS65) others (KatcS56a) Δ −85.40 (EvaJS65)	A chem, genet (LindnM48a, EvaJS65) parent Rh^{101m} (LindnM48a, EvaJS65)	γ Rh X-rays, 0.270 (8%), 0.296 (30%), 0.511 (5%, $\gamma^{\pm}$), 0.566 (7%), 0.590 (24%), 0.723 (5%), 0.993 (1.7%), 1.20 (3.3%, complex), 1.30 (3.3%, doublet) β^+ 0.78 max e^- 0.021 daughter radiations from Rh^{101m}	Rh^{103}(p, 3n) (EvaJ65) Ru^{99}(α, 2n) (KatcS56a)
Pd^{102}		% 0.96 (SitJ53) 0.8 (SamM36a) Δ −87.92 (MTW) σ_c 4.8 (GoldmDT64)			
Pd^{103}	17.0 d (MatthD47, BrosA46, MeiW53) 17.5 d (RieL54)	☢ EC (BrosA46) Δ −87.46 (MTW)	A chem, genet (BrosA46) chem, excit (MatthD47) parent Rb^{103m} (BrosA46, MeiJ50a) daughter Ag^{103} (HaldB54)	γ Rh X-rays, 0.297 (0.011%), 0.362 (0.06%), 0.498 (0.011%) daughter radiations from Rh^{103m}	Pd^{102}(n, γ) (BrosA46) Rh^{103}(d, 2n) (MatthD47, LindnM48a) Rh^{103}(p, n) (MatthD47)
Pd^{104}		% 10.97 (SitJ53) 9.3 (SamM36a) Δ −89.41 (MTW)			
Pd^{105}		% 22.2 (SitJ53) 22.6 (SamM36a) Δ −88.43 (MTW)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (△≡M−A), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{46}Pd^{106}$		% 27.3 (SitJ53) 27.2 (SamM36a) △ −89.91 (MTW) σ_c 0.29 (GoldmDT64)			
Pd^{107}	≈7 x 10^6 y sp act (ParkG49)	☢ β^- (ParkG49) △ −88.368 (MTW)	B chem (ParkG49)	β^- 0.04 max γ no γ	fission (ParkG49)
Pd^{107m}	21.3 s (StriT57a) 23 s (SchinU58, FlaA52a)	☢ IT (FlaA52a) △ −88.16 (LHP, MTW)	A excit (FlaA52a) n-capt, sep isotopes (SchinU58, WeirW64) genet energy levels (CujB63)	γ Pd X-rays, 0.21 e^- 0.19, 0.21	$Pd^{106}(n,\gamma)$, $Pd^{108}(n,2n)$ (SchinU58, WeirW64)
Pd^{108}		% 26.7 (SitJ53) 26.8 (SamM36a) △ −89.52 (MTW) σ_c 12 (to Pd^{109}) 0.2 (to Pd^{109m}) (GoldmDT64)			
Pd^{109}	13.47 h (BranHW62) 13.6 h (MeiW53, BonaG64) 13.1 h (WafH48) 14.1 h (MacD48) others (KraJD37, SeiJ51, KondE52, DzaB57)	☢ β^- (KraJD37) △ −87.60 (MTW)	A n-capt (An. E35) chem, excit (KraJD37) chem, mass spect (RalW46, BergI49) parent Ag^{109m} (SegE41, SiegK49a, SeiJ51) [daughter Rh^{109}] (SeiJ51)	β^- 1.028 max e^- 0.062 (with Ag^{109m}), 0.084 (with Ag^{109m}) γ Ag X-rays, 0.088 (5%, with Ag^{109m}), 0.129 (0.013%), 0.31 (0.010%, doublet), 0.41 (0.010%, doublet), 0.60 (0.03%), 0.64 (0.010%)	$Pd^{108}(n,\gamma)$ (AmaE35, KraJD37, SerL47b, OrsA49, HumV51)
Pd^{109m}	4.69 m (StarJ59) 4.75 m (StriT57a) others (FlaA52a, MangS62, OkaM63)	☢ IT (KahJ51, FlaA52a) △ −87.41 (LHP, MTW)	A n-capt (KahJ51) excit, cross bomb, n-capt (FlaA52a) n-capt, sep isotopes, excit (SchinU58) genet energy levels (CujB63)	γ Pd X-rays, 0.188 (58%) e^- 0.164, 0.185	$Pd^{108}(n,\gamma)$ (FlaA52a, SchinU58)
Pd^{110}		% 11.8 (SitJ53) 13.5 (SamM36a) △ −88.34 (MTW) σ_c 0.2 (to Pd^{111}) 0.04 (to Pd^{111m}) (GoldmDT64)			
Pd^{111}	22 m (DzaB57, MGinC52) others (SegE41)	☢ β^- (KraJD37) △ −86.0 (MTW)	A n-capt (AmaE35) chem, genet (SegE41) parent Ag^{111} (KraJD37, SegE41, JohaS50) parent Ag^{111m} (SchinU57)	β^- 2.2 max γ 0.38 (↑ 5), 0.60 (↑ 13, doublet), 0.81 (↑ 1), 1.4 (↑ 8, doublet) daughter radiations from Ag^{111m}	$Pd^{110}(n,\gamma)$, daughter Pd^{111m} (AmaE35, KraJD37, SerL47b)
Pd^{111m}	5.5 h (MGinC52, DzaB57)	☢ IT 75%, β^- 25% (MGinC52) △ −85.8 (LHP, MTW)	A chem, genet (MGinC52, DzaB57) parent Ag^{111} (MGinC52, DzaB57)	β^- 2.0 max e^- 0.148, 0.169 γ Pd X-rays, 0.17 daughter radiations from Pd^{111}, Ag^{111m}, Ag^{111}	$Pd^{110}(n,\gamma)$ (DzaB57, PraW60) $Pd^{110}(d,p)$ (MGinC52, EccS62)
Pd^{112}	21.0 h (GirR59k) 21 h (SeiJ51)	☢ β^- (NisY40b) △ −86.27 (MTW)	A chem, genet (NisY40b, SegE41) parent Ag^{112} (NisY40b, NisY40, SegE41, SeiJ51)	β^- 0.28 max e^- [0.016] γ [Pd L X-rays], 0.019 (20%) daughter radiations from Ag^{112}	fission (SegE41, TurA51a, KatcS48, NisY40b, NisY40, SeiJ51, GoeR49, NewA49)
Pd^{113}	1.4 m (AlexJ58) 1.5 m (HicH54, PouA60)	☢ [β^-] (HicH54)	A chem, genet (HicH54, AlexJ58) parent 5.3 h Ag^{113} (HicH54, AlexJ58) parent 1.2 m Ag^{113} (AlexJ58)	γ no γ daughter radiations from 5.3 h Ag^{113} and 1.2 m Ag^{113}	fission (AlexJ58, HicH54) $Cd^{116}(n,\alpha)$ (PouA60)
Pd^{114}	2.4 m (AlexJ58)	☢ [β^-] (AlexJ58)	D chem, genet (AlexJ58) parent 5 s Ag^{114} (AlexJ58) not parent 2 m Ag^{114} (AlexJ58)	γ no γ	fission (AlexJ58)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV (C^{12} = 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{46}$Pd^{115}	45 s genet (AlexJ58)	☢ [β^-] (AlexJ58)	B chem, genet (AlexJ58) parent 20 m Ag^{115}, parent 20 s Ag^{115} (AlexJ58)		fission (AlexJ58)
$_{47}$Ag^{102}	15 m (AmeO60) 16 m (EnnT39)	☢ [EC, β^+] (EnnT39, AmeO60) Δ -83 (MTW)	C excit (EnnT39) excit, sep isotopes (AmeO60)		Pd^{102}(p, n) (AmeO60, EnnT39)
Ag^{103}	66 m (PatA62b, HaldB54, BendW53) 69 m (PreiI60a) 59 m (JohnFA55)	☢ β^+, EC (HaldB54) EC(K) ≈70% (KuzM57) Δ -84.9 (MTW)	A chem (BendW53) chem, genet (HaldB54) chem, excit (GirR59e) excit, sep isotopes (AmeO60, PatA62b) parent Pd^{103} (HaldB54) daughter Cd^{103} (PreiI60a)	β^+ 1.6 max γ Pd X-rays, 0.12 (↑ 26, doublet), 0.15 (↑ 23), 0.24 (↑ 10), 0.27 (↑ 34), 0.511 (↑ 100, $\gamma^{\pm}$), 1.01 (↑ 10, complex), 1.16 (↑ 9), 1.28 (↑ 13) daughter radiations from Pd^{103}	Rh^{103}(α, 4n) (GirR59e) Pd^{104}(p, 2n) (AmeO60) Pd^{102}(d, n) (BendW53) Pd^{102}(p, γ) (PatA62b)
Ag^{103m}	5.7 s (WhiW62)	☢ IT (WhiW62) Δ -84.7 (LHP, MTW)	C excit (WhiW62)	γ Ag X-rays, 0.138 e^- [0.113, 0.135]	Pd^{104}(p, 2n) (WhiW62)
Ag^{104}	66 m (NutH60) 70 m (GirR59e) 69 m (AmeO60) others (EnnT39)	☢ β^+, EC (LindnM50a) Δ -85.14 (MTW)	A excit (EnnT39) chem, excit (GirR59e) sep isotopes, excit (AmeO60)	β^+ 0.99 max e^- 0.532, 0.743 γ Pd X-rays, 0.511 ($\gamma^{\pm}$), 0.556 (84%), 0.764 (48%), 0.854 (30%), 1.34 (8%), 1.53 (7%), 1.62 (8%), 1.81 (7%)	Rh^{103}(α, 3n) (GirR59e, NutH60, EwbW59)
Ag^{104m}	29.8 m (NutH60) 27 m (GirR59e, AmeO60, JohnFA55)	☢ β^+, EC (JohnFA55, GirR59e) IT 20-40% (AmeO60) Δ -85.12 (LHP, MTW)	A chem (JohnFA55) excit (GirR59) excit, sep isotopes (AmeO61) daughter Cd^{104} (JohnFA55, PreiI60a)	β^+ 2.70 max e^- 0.532 γ Pd X-rays, 0.511 (120%, $\gamma^{\pm}$), 0.556 (100%) daughter radiations from Ag^{104}	Rh^{103}(α, 3n) (GirR59e, NutH60, EwbW59) daughter Cd^{104} (JohnFA55, PreiI60a)
Ag^{105}	40 d (GumJ50) others (EnnT39)	☢ EC, no β^+ (GumJ50) Δ -87 (MTW)	A excit (EnnT39) chem, excit (BradH47a)	γ Pd X-rays, 0.064 (10%), 0.280 (32%), 0.344 (42%, complex), 0.443 (10%), 0.62-0.68 (12%, complex), 1.088 (2%) e^- 0.040, 0.060, 0.256, 0.320	Rh^{103}(α, 2n) (BradH47a, GumJ50, MeiJ50b) protons, deuterons on Pd (EnnT39, GumJ50, MeiJ50b, SutT61a, BoeR58, EwbW63)
Ag^{106}	23.96 m (EbrT65) 24.3 m (MocD48) 24.0 m (BendW51, BendW53) others (PoolM38, ForS52, DubL38, EnnT39)	☢ β^+ (KraJD37) β^+, EC, β^- (?) ≈1% (BendW53) Δ -86.94 (MTW)	A chem, excit (BotW37, HeyF37) chem, excit, cross bomb (KraJD37, PoolM38)	β^+ 1.96 max γ Pd X-rays, 0.511 (140%, 0.512 γ + $\gamma^{\pm}$)	Rh^{103}(α, n) (PoolM38, BradH47a)
Ag^{106m}	8.5 d (SmiW61b) 8.2 d (PoolM38) 8.4 d (RobiR60)	☢ EC (HurL44) no β^+, lim 0.1% (BendW53) Δ -86.6 (LHP, MTW)	A chem, excit, cross bomb (KraJD37, PoolM38)	γ Pd X-rays, 0.221 (9%), 0.451 (9%), 0.512 (86%), 0.616 (23%), 0.717 (31%, complex), 0.748 (13%), 0.80 (41%, complex), 1.046 (29%), 1.128 (9%), 1.199 (9%), 1.528 (15%), 1.58 (8%), 1.83 (3%) e^- 0.197, 0.382, 0.405, 0.426, 0.487, 0.508, 0.592, 0.693	Rh^{103}(α, n) (PoolM38, BradH47a, MeiJ50b, SmiW61b)
Ag^{107}		% 51.35 (WhiJ48) Δ -88.403 (MTW) σ_c 35 (to Ag^{108}) (GoldmDT64)			
Ag^{107m}	44.3 s (BradH47a, BradH45b) others (WoliEJ51, AlvL40a)	☢ IT (AlvL40a) Δ -88.310 (LHP, MTW)	A chem, genet (AlvL40a, HelmhA41b) daughter Cd^{107} (AlvL40a, HelmhA41b, BradH45a, HelmhA46, BradH47a)	γ Ag X-rays, 0.094 (5%) e^- 0.068, 0.090	daughter Cd^{107} (AlvL40a, HelmhA41b, BradH45a, HelmhA46, BradH47a)
Ag^{108}	2.42 m (WahM60) 2.41 m (EbrT65) others (SchM57, AmaE35, PerlmM48, MocD48, BotW39, FlaA44)	☢ β^- 97.5%, EC 2.2%, β^+ 0.28% (FrevL65, FrevL62) β^- 95.7%, EC 3.9%, β^+ 0.36% (WahM60) Δ -87.61 (MTW)	A chem, n-capt (AmaE35) excit, cross bomb (PoolM38) daughter Ag^{108m} (WahM60)	β^- 1.64 ma β^+ 0.90 max γ Pd X-rays, 0.434 (0.45%), 0.511 (0.56%, $\gamma^{\pm}$), 0.615 (0.18%), 0.632 (1.7%)	daughter Ag^{108m} (WahM60) Ag^{107}(n, γ) (FlaA44b, AmaE35, FlaA44, SerL47b)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}≡0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{47}Ag^{108m}$	>5 y (WahM60)	☢ EC 90%, IT 10% (WahM60) Δ −87.50 (LHP, MTW)	A chem, n-capt, genet (WahM60) parent Ag^{108} (WahM60)	γ Pd X-rays, Ag X-rays, 0.080 (5%), 0.434 (89%), 0.614 (90%), 0.722 (90%) e^- 0.027 daughter radiations from Ag^{108}	$Ag^{107}(n,\gamma)$ (WahM60)
Ag^{109}		% 48.65 (WhiJ48) Δ −88.717 (MTW) σ_c 89 (to Ag^{110}) 3 (to Ag^{110m}) (GoldmDT64)			
Ag^{109m}	39.2 s (BradH46, BradH47a) 40 s (WoliEJ51, WieM45, SchinU57)	☢ IT (HelmhA41b) Δ −88.630 (LHP, MTW)	A chem, genet (HelmhA41b) daughter Pd^{109} (SegE41, SiegK49a, SeiJ51) daughter Cd^{109} (HelmhA41b), BradH46, HelmhA46, BradH45a)	γ Ag X-rays, 0.088 (5%) e^- 0.062, 0.084	daughter Cd^{109} (HelmhA41b, BradH46, HelmhA46) daughter Pd^{109} (SegE41, SiegK49a, SeiJ51)
Ag^{110}	24.4 s (MalmS62) 24.5 s (HirzO46) others (SehM57, BolF54, ThieP62, AmaE35, PoolM38, FlaA44, GaeE36, SerL47b, HirzO47a)	☢ β^- (PoolM38) EC 0.3% (FrevL65) no β^+, lim 10^{-3}% (BereD62b) β^+ ≈6 x 10^{-4}% (BadN62) Δ −87.47 (MTW)	A n-capt (AmaE35) sep isotopes, n-capt (FlaA44b) chem, genet (MiskJ50) daughter Ag^{110m} (MiskJ50)	β^- 2.87 max γ 0.658 (4.5%)	daughter Ag^{110m} (MiskJ50) $Ag^{109}(n,\gamma)$ (AmaE35, GaeE36, FlaA44, SerL47b, FrevL65)
Ag^{110m}	255 d (EasH60) 253 d (GeiKW57, ThirH57) 249 d (NilR62) others (CaliJ59, SchinJ64, GumJ50, ColoJ64, CorkJ50h, LivJ38c, CorkJ48b)	☢ β^- 98.7%, IT 1.3% (calc from SutT63, NewW64, GeiJ65 by LHP) Δ −87.35 (LHP, MTW) σ_c 80 (GoldmDT64)	A chem, n-capt (RedH38) resonance neutron activation (GoldhM46) chem, mass spect (BergI49) parent Ag^{110} (MiskJ50)	β^- 1.5 max (0.6%), 0.53 max (31%), 0.087 max e^- 0.090, 0.113 γ 0.658 (96%), 0.68 (16%, doublet), 0.706 (1[illegible]%), 0.764 (23%), 0.818 (8%), 0.885 (71%), 0.937 (32%), 1.384 (21%), 1.505 (11%) daughter radiations from Ag^{110}	$Ag^{109}(n,\gamma)$ (RedH38, LivJ38c, AlexK38, MitA38, SerL47b)
Ag^{111}	7.5 d (JohaS50, KraJD37, PoolM38, StorA50) 7.6 d (SteinE51b) 7.3 d (DzaB57) others (KunD47, HirzO47a, DufR49, LindnM50a, GoeR49, DConP48, NisY40b, TurA51a, FinB51c)	☢ β^- (KraJD37) Δ −88.20 (MTW)	A chem, excit (KraJD37) chem, excit, cross bomb (PoolM38) daughter Pd^{111} (KraJD37, SegE41, JohaS50) daughter Pd^{111m} (MGinC52, DzaB57)	β^- 1.05 max average β^- energy: 0.38 ion ch (BrabJ53) γ 0.247 (1%), 0.342 (6%)	$Pd^{110}(n,\gamma)Pd^{111}$ + $Pd^{111m}(\beta^-)$ (KraJD37) $Pd^{110}(d,n)$ (KraJD37, PoolM38, ZimK49)
Ag^{111m}	74 s (SchinU57)	☢ IT, no β^-, lim 1% (SchinU57) Δ −88.13 (LHP, MTW)	B chem, genet (SchinU57) daughter Pd^{111} (SchinU57)	γ [Ag X-rays], 0.065 e^- [0.040, 0.062]	daughter Pd^{111} (SchinU57)
Ag^{112}	3.14 h (InoH62) 3.2 h (PoolM38, HirzO47a)	☢ β^- (PoolM38a) Δ −86.57 (MTW)	A chem, excit, cross bomb (PoolM38) daughter Pd^{112} (NisY40b, NisY40, SegE41, SeiJ51)	β^- 3.94 max γ 0.617 (41%), 1.40 (5%), 1.63 (3%), 2.11 (3%), 2.55 (2%), many others between 0.3 and 3.3	daughter Pd^{112} (NisY40b, NisY40, SegE41, SeiJ51) $In^{115}(n,\alpha)$ (PoolM38) $Cd^{114}(d,\alpha)$ (InoH62)
Ag^{113}	5.3 h (AlexJ58, TurA47, DufR49, VasiI58)	☢ β^- (TurA47) Δ −87.04 (MTW)	A chem (TurA47) chem, sep isotopes, excit (DufR49) daughter Pd^{113} (HicH54, AlexJ58)	β^- 2.0 max γ 0.12 (↑ 10), 0.30 (↑ 100), 0.58 (↑ 5), 0.67 (↑ 17), 0.88 (↑ 4), 0.98 (↑ 5), 1.18 (↑ 4)	fission (TurA47, FolR5[illegible]) $Cd^{114}(\gamma,p)$ (DufR49)
Ag^{113}	1.2 m (AlexJ58)	☢ β^- (AlexJ58)	B chem, genet (AlexJ58) daughter Pd^{113} (AlexJ58)	β^- <2.0 max γ 0.14, 0.30, 0.39, 0.56, 0.70	fission (AlexJ58)
Ag^{114}	4.5 s (PouA60) 5s (AlexJ58)	☢ β^- (AlexJ58) Δ −85.4 (MTW)	C chem, genet (AlexJ58) daughter Pd^{114} (AlexJ58)	β^- 4.6 max γ 0.57	fission, daughter Pd^{114} (AlexJ58) $Cd^{114}(n,p)$ (PouA60)
Ag^{114}	2 m (DufR49) 3 m (SeeW47)	☢ β^- (DufR49)	E chem (TurA47, SeeW47) chem, excit, sep isotopes (DufR49) not daughter Pd^{114} (AlexJ58)	β^- hard β^-	$Cd^{114}(n,p)$ (DufR49) fission (TurA47, SeeW47) not observed in $Cd^{114}(n,p)$ (AlexJ58)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12} ≡ 0); Thermal neutron cross section (σ), barns		Class; Identification; Genetic relationships		Major radiations: approximate energies (MeV) and intensities		Principal means of production
${}_{47}$Ag^{115}	20.0 m (BahE64) 21.1 m (AlexJ58) others (DufR49, SeeW47, WahA52)	☢ Δ	β^- (TurA47) -84.8 (MTW)	A	chem (TurA47, SeeW47) chem, excit, sep isotopes (DufR49) parent Cd^{115} (91%), parent Cd^{115m} (9%) (WahA52) parent Cd^{115} (92%), parent Cd^{115m} (8%) (HicH55) daughter Pd^{115} (AlexJ58)	β^- γ	3.2 max 0.14 (12%, complex), 0.22 (49%, complex), 0.28 (13%), 0.36 (11%), 0.42 (7%), 0.47 (10%), 0.64 (4%, complex), 1.48 (11%), 1.66 (8%), 1.89 (10%, complex), 2.12 (13%)	fission (TurA47, SeeW47, BahE64, AlexJ58) Cd^{116}(γ,p) (DufR49)
Ag^{115}	≈20 s (AlexJ58)	☢	[β^-] (AlexJ58)	B	chem, genet (AlexJ58) daughter Pd^{115}, parent Cd^{115} (AlexJ58)			fission (AlexJ58)
Ag^{116}	2.5 m (AlexJ58)	☢ Δ	β^- (AlexJ58) -83 (MTW)	D	chem (AlexJ58)	β^- γ	5.0 max 0.52, 0.70	fission (AlexJ58)
Ag^{117}	1.1 m (AlexJ58)	☢	[β^-] (AlexJ58)	B	chem, genet (AlexJ58) parent Cd^{117} and/or Cd^{117m} (AlexJ58)			fission (AlexJ58)
${}_{48}$Cd^{103}	10 m (PreiI60a)	☢	β^+, [EC] (PreiI60a)	A	chem, genet (PreiI60a) parent Ag^{103} (PreiI60a)	γ	Ag X-rays, 0.22, 0.511 ($\gamma^{\pm}$), 0.63, 0.85 daughter radiations from Ag^{103}	O^{16} on Mo (PreiI60a)
Cd^{104}	57 m (PreiI60a) 54 m (KurcB55) 59 m (JohnFA55)	☢ Δ	EC, no β^+ (JohnFA55) -84 (MTW)	A	chem, genet, excit (JohnFA55) parent Ag^{104m} (JohnFA55, PreiI60a)	γ e^-	Ag X-rays, 0.084 0.041, 0.058, 0.080 daughter radiations from Ag^{104m} Ag^{104}	Ag^{107}(p, 4n) (JohnFA55) O^{16} on Mo (PreiI60a)
Cd^{105}	55 m (JohnFA53) 57 m (GumJ50)	☢ Δ	EC, β^+ (GumJ50) -84 (MTW)	B	cross bomb (GumJ50) chem, excit (JohnFA53)	β^+ e^- γ	1.69 max 0.282, 0.295, 0.321, 0.408, others [Ag X-rays, 0.308, 0.320, 0.347, 0.433, 0.511 ($\gamma^{\pm}$), others to 2.3] daughter radiations from Ag^{105}	Pd^{102}(α, n) (GumJ50) Ag^{107}(p, 3n) (JohnFA53)
Cd^{106}		% Δ σ_c	1.22 (LelW48) -87.128 (MTW) 1 (GoldmDT64)					
Cd^{107}	6.49 h (LarN62) 6.7 h (DelL39, HelmhA41b) 6.4 h (ValleG39)	☢ Δ	EC 99+%, β^+ 0.28% (LarN62) -86.99 (MTW)	A	chem (DelL39) chem, n-capt, sep isotopes (HelmhA46) parent Ag^{107m} (AlvL40a, HelmhA41b, BradH45a, HelmhA46, BradH47a)	β^+ γ	0.302 max Ag X-rays, 0.511 (0.56%, $\gamma^{\pm}$), 0.796 (0.08%), 0.829 (0.21%) daughter radiations from Ag^{107m}	Cd^{106}(n, γ) (HelmhA46) Ag^{107}(d, 2n) (AlvL40a, KriR39, KriR40a, HelmhA41b) Ag^{107}(p, n) (DelL39, ValleG39)
Cd^{108}		% Δ σ_c	0.88 (LelW48) -89.248 (MTW) 3 (GoldmDT64)					
Cd^{109}	453 d (LeuH65) 470 d (GumJ50) others (MangS62, BradH46)	☢ Δ	EC (HelmhA41b) no β^+ (DreB51) -88.55 (MolR65, MTW)	A	chem (KriR40a) chem, n-capt, sep isotopes (HelmhA46) parent Ag^{109m} (HelmhA41b, BradH45a, HelmhA46, BradH46)	γ e^-	Ag X-rays, 0.088 (with Ag^{109m}), 0.062 (with Ag^{109m}), 0.084 (with Ag^{109m})	Cd^{108}(n, γ) (HelmhA46, CorkJ50g) Ag^{109}(d, 2n) (KriR40a, HelmhA41b, GumJ50)
Cd^{110}		% Δ σ_c	12.39 (LelW48) -90.342 (MTW) 0.1 (to Cd^{111m}) (GoldmDT64)					
Cd^{111}		% Δ	12.75 (LelW48) -89.246 (MTW)					
Cd^{111m}	48.6 m (MGinC51) 48.7 m (WieM45)	☢ Δ	IT (FelJ41, WieM45) -88.850 (LHP, MTW)	A	chem (DodM38) chem, sep isotopes, n-capt (GoldhM48a) daughter In^{111} (0.01%) (MGinC51a)	γ e^-	Cd X-rays, 0.150 (30%), 0.247 (94%) 0.123, 0.146	Cd^{110}(n, γ) (GoldhM48a, DodM38, HoleN48b) daughter In^{111} (MGinC51a)

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$_{48}Cd^{112}$		☢ 24.07 (LelW48) Δ −90.575 (MTW) σ_c 0.03 (to Cd^{113m}) (GoldmDT64)			
Cd^{113}	$t_{1/2}$ >1.3 × 10^{15} y sp act (WatD62a)	% 12.26 (LelW48) Δ −89.041 (MTW) σ_c 20, 000 (GoldmDT64)			
Cd^{113m}	13.6 y (FlyK65a) 14 y (WahA59) 5 y (CarsW50)	☢ β^- (CarsW50) IT weak (DMatE56) Δ −88.77 (LHP, MTW)	A chem, excit, sep isotopes (CarsW50)	β^- 0.58 max γ [Cd X-rays], 0.265 (≈0.1%)	Cd^{112}(n, γ)+Cd^{113}(n, n') (CarsW50) fission (WahA52, WahA59)
Cd^{114}		% 28.86 (LelW48) Δ −90.018 (MTW) σ_c 1.1 (to Cd^{115}) 0.14 (to Cd^{115m}) (GoldmDT64)			
Cd^{115}	53.5 h (WyaE61) 53 h (WahA52, VasiI58) 54 h (CorkJ50g, BedaA64) others (LawJL40, MetR51a)	☢ β^- (CorkJ37) Δ −88.09 (MTW)	A chem (CorkJ37) chem, genet (GoldhM38) chem, sep isotopes, n-capt (CorkJ50g) parent In^{115m} (GoldhM38, CorkJ39, [illegible]isY40, MetR51a, WahA52, LangeL52a) daughter 20 m Ag^{115} (91%) (WahA52) daughter 20 m Ag^{115} (92%) (HicH55) daughter ≈20 s Ag^{115} (AlexJ58)	β^- 1.11 max γ In X-rays, 0.230 (0.6%), 0.262 (2%), 0.49 (10%), 0.53 (26%) daughter radiations from In^{115m}	Cd^{114}(n, γ) (GoldhM38, MitA37, SerL47b)
Cd^{115m}	43 d (SerL47, CorkJ50g) 44 d (GleL51g, WahA59)	☢ β^- (CorkJ39) Δ −87.91 (LHP, MTW)	A chem, excit (SerL47) chem, sep isotopes, n-capt (CorkJ50g) daughter 20 m Ag^{115} (9%) (WahA52) daughter 20 m Ag^{115} (8%) (HicH55)	β^- 1.62 max γ 0.485 (0.31%), 0.935 (1.9%), 1.29 (0.9%)	Cd^{114}(n, γ) (SerL47b, SerL47, CorkJ50g)
Cd^{116}	$t_{1/2}$ (ββ) >10^{17} y sp act (WintR55)	% 7.58 (LelW48) Δ −88.712 (MTW) σ_c 1.4 (to Cd^{117}) (GoldmDT64) 0.7 (to Cd^{117m}) (TanC66a, GoldmDT64)			
Cd^{117}	2.4 h (TanC66) ≈3 h (SharmR64, MancR65) others (CoryC53, AteA52, LawJL40, MetR51b)	☢ β^- (SharmR64) Δ −86.41 (MTW)	A chem, genet, n-capt (SharmR64, TanC66) parent In^{117m} (93%), parent In^{117} (7%) (TanC66) not daughter Cd^{117m} (SharmR64) others (CorkJ39, GoldhM38, LawJL40, MetR51b, MGinC55)	β^- 2.23 max e^- 0.286 (with In^{117m}) γ In X-rays (with In^{117m}), 0.089 (7%), 0.273 (31%), 0.314 (16%, with In^{117m}), 0.345 (18%), 0.434 (13%), 0.832 (4%), 0.880 (3%), 0.95 (4%, doublet), 1.052 (5%), 1.303 (19%), 1.577 (17%) daughter radiations from In^{117m}, In^{117}	Cd^{116}(n, γ) (TanC66a) Cd^{116}(d, p) (TanC66a)
Cd^{117m}	3.4 h (TanC66) ≈3 h (SharmR64, MancR65) others (CoryC53, AteA52, LawJL40, MetR51b)	☢ β^- (SharmR64) Δ −86.27 (LHP, MTW)	A chem, genet, n-capt (SharmR64, TanC66) parent In^{117} (56%), parent In^{117m} (44%) (TanC66) not parent Cd^{117} (SharmR64) others (CorkJ39, GoldhM38, LawJL40, MetR51b, MGinC55)	β^- [1.91 max (weak)], 0.67 max e^- 0.286 (with In^{117m}) γ In X-rays (with In^{117m}), 0.273 (18%), 0.314 (8%, with In^{117m}), 0.345 (4%), 0.434 (4%), 0.565 (6%), 0.715 (4%), 0.880 (10%), 1.065 (9%), 1.117 (4%), 1.24 (11%, complex), 1.338 (8%), 1.408 (8%), 1.433 (10%), 1.562 (6%), 1.998 (15%), 2.319 (3%)	Cd^{116}(n, γ) (TanC66a) Cd^{116}(d, p) (TanC66a)
Cd^{117}	≈50 m (CoryC53)		G chem, genet (CoryC53) activity not observed (SharmR64, TanC66)		

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$_{48}$Cd^{118}	49 m (GleC61)	☢ β^- (CoryC53) Δ -87 (MTW)	B chem, excit (CoryC53) chem, genet (GleC61) parent 5.0 s In^{118} (CoryC53, GleC61) not parent 4.4 m In^{118} (CoryC53, GleC61)	daughter radiations from 5.0 s In^{118}	fission (CoryC53, GleC61)
Cd^{119}	2.7 m (GleC61a)	☢ β^- (GleC61a) Δ -84.1 (MTW)	B chem, genet (GleC61a) parent In^{119}, parent In^{119m} (GleC61a)	β^- 3.5 max daughter radiations from In^{119m}, In^{119}	fission (GleC61a)
Cd^{119}	10 m (NusN57, GleC61a)	☢ β^- (NusN57, GleC61a) Δ -84.1 (MTW)	B chem, genet (NusN57, GleC61a) parent In^{119m} (NusN57, GleC61a)	β^- 3.5 max daughter radiations from In^{119m}, In^{119}	Sn^{122}(d, αp) (NusN57) fission (GleC61a)
Cd^{121}	12.8 s (WeisH65)	☢ [β^-] (WeisH65)	B chem, genet (WeisH65) ancestor Sn^{121} (WeisH65)		fission (WeisH65)
Cd$^{(121?)}$	3.5 m (NusN57)	☢ [β^-] (NusN57)	C chem, excit (NusN57) parent 11.5 m In$^{(121?)}$ and 32 m In$^{(121?)}$ (NusN57) Daughter In isotopes are probably incorrectly assigned (NDS, YutH60)		deuterons on Sn (NusN57)
$_{49}$In^{106}	5.3 m (CatR62) others (CatR65)	☢ β^+ (CatR62), [EC] Δ -80.6 (MTW)	A chem, excit, sep isotopes (CatR62)	β^+ 4.9 max γ [Cd X-rays], 0.511 ($\gamma^\pm$), 0.63, 1.65, 1.85, many others	Cd^{106}(p, n) (CatR62)
In^{107}	33 m (MallE49) 31 m (BasuB63) 30 m (MaclK52)	☢ β^+, EC (BasuB63) Δ -83.5 (MTW)	A chem, sep isotopes (MallE49) mass spect (MaclK52)	β^+ 2.2 max γ Cd X-rays, 0.22 (46%), 0.32, 0.511 ($\gamma^\pm$), 0.73, 0.84, 0.94, 1.05, 1.25 daughter radiations from Cd^{107}, Ag^{107m}	Cd^{106}(d, n) (MallE49, CassW55a) Cd^{106}(p, γ) (MallE49, BasuB63)
In^{108}	57 m (KatoT63) 55 m (MeaS55, MallE49) others (KatoT62b, MGinC51)	☢ EC, β^+ (KatoT62b) Δ -84.14 (KatoT62b, MTW)	A chem, sep isotopes (MallE49) mass spect (MaclK52)	β^+ 1.29 max e^- 0.123, 0.147, 0.216, 0.238, 0.260, 0.606, 0.845 γ Cd X-rays, 0.150, 0.175, 0.243, 0.511 ($\gamma^\pm$), 0.633, 0.872	Ag^{107}(α, 3n) (KatoT62a, KatoT62b)
In^{108}	39 m (KatoT63) 40 m (MeaS55, KatoT62b)	☢ EC, β^+ (KatoT62b) Δ -84.10 (KatoT62b, MTW)	B chem, excit (MeaS55) genet energy levels (KatoT62b) daughter Sn^{108} (MeaS55)	β^+ 1.50 max e^- 0.606 γ Cd X-rays, 0.383, 0.511 ($\gamma^\pm$), 0.633, 0.842	Ag^{107}(α, 3n) (KatoT62a, KatoT62b)
In^{109}	4.3 h (MallE49, NozM62) 4.2 h (MGinC51) 5.2 h (GhoS48) others (TenD47a)	☢ EC 94%, β^+ 6% (PetrM56a) Δ -86.53 (MTW, MolR65)	A chem, excit (TenD47a) chem, mass spect (GhoS48) chem, excit, sep isotopes (MallE49) descendant Sn^{109} (PetrM56a)	β^+ 0.79 max e^- 0.033, 0.056, 0.178, 0.201 γ Cd X-rays, 0.205, 0.28 (complex), 0.35 (complex), 0.65 (complex), 0.91 (complex)	Ag^{107}(α, 2n) (NozM62, KatoT62a, TenD47a)
In^{109m_1}	1.3 m (AlexKF65) <2m (PetrM56a)	☢ IT (PetrM56a) Δ -85.87 (LHP, MTW)	C genet (PetrM56a) daughter Sn^{109} (PetrM56a)	γ 0.658 e^- 0.630	daughter Sn^{109} (PetrM56a)
In^{109m_2}	0.20 s (AlexKF65) 0.21 s (DemiA65) 0.22 s (PoeG63)	☢ IT (AlexKF65, DemiA65) Δ -84.42 (LHP, MTW)	C excit, cross bomb (AlexKF65, DemiA65, PoeG63)	γ 0.17 (12%), 0.21 (12%), 0.40 (20%), 0.68 (100%), 1.04 (20%), 1.43 (77%)	Ag^{107}(α, 2n) (AlexKF65, DemiA65) Rh^{103}(C^{12}, α2n) (AlexKF65)
In^{110}	66 m (KatoT62a, BarnS39a) 69 m (HamiJ63) 65 m (GhoS48)	☢ β^+ 71%, EC 29% (NaiT64) Δ -86.41 (MTW)	A chem (BarnS39a) chem, excit, mass spect (GhoS48) daughter Sn^{110} (MeaS55)	β^+ 2.25 max e^- 0.631 γ Cd X-rays, 0.511 (142%, $\gamma^\pm$), 0.658 (95%)	daughter Sn^{110} (NaiT64) Ag^{107}(α, n) (KatoT62a) Ag^{109}(α, 3n) (FukS65)

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$_{49}$In^{110}	4.9 h (BleE51, KatoT62a) 5.0 h (MGinC51) others (GhoS48)	☢ EC, β^+ ? (weak) (KatoT62a) no IT, lim 0.008% (HamiJ63)	A chem (GhoS48) chem, genet energy levels (MGinC51a, BleE51) not daughter Sn^{110} (MeaS55)	γ Cd X-rays, 0.66 (↑ 160, complex), 0.91 (↑ 110, complex) e^- 0.094, 0.558, 0.615, 0.631, 0.653, 0.680, 0.858, 0.910	Ag^{109}(α, 3n) (FukS65, KatoT62a)
In^{111}	2.81 d (MaiA57) 2.84 d (MGinC51) others (BarnS39a, CorkJ39)	☢ EC (LawJL40) no β^+, lim 0.06% (MGinC51) Δ −88.2 (MTW)	A chem (CorkJ39) chem, excit (TenD47, GhoS48) mass spect (GhoS48) parent Cd^{111m} (0.01%) (MGinC51a)	γ Cd X-rays, 0.173 (89%), 0.247 (94%) e^- 0.146, 0.220, 0.243	Ag^{109}(α, 2n) (FukS65, LawJL40, TenD47, GhoS48, MGinC51)
In^{112}	14.[illegible] m (FukS65) 12 m (RuaJ62a) 11 m (GirR59i) 15 m (BleE53)	☢ β^- 44%, β^+ 22%, EC 34% (calc) (RuaJ62a) others (BleE53) Δ −87.98 (MTW)	A chem, cross bomb, excit (SmiRN42) chem, excit (TenD47) daughter In^{112m} (SmiRN42, TenD47, GoldsG50)	β^- 0.66 max β^+ 1.56 max γ Cd X-rays, 0.511 (44%, $\gamma^{\pm}$), 0.617 (6%)	Ag^{109}(α, n) (FukS65, SmiRN42, TenD47, RuaJ62a, KatoT62a)
In^{112m}	20.7 m (BleE53) others (RuaJ62a, GirR59i, BarnS39a, TenD47)	☢ IT (SmiRN42, TenD47) Δ −87.83 (LHP, MTW)	A chem (BarnS39a) chem, cross bomb, excit (SmiRN42) chem, excit (TenD47) parent In^{112} (SmiRN42, TenD47, GoldsG50)	γ In X-rays, 0.156 (9%) e^- 0.128, 0.152 daughter radiations from In^{112}	Ag^{109}(α, n) (SmiRN42, TenD47, RuaJ62a, KatoT62a)
In^{113}		% 4.23 (WhiJ48) 4.33 (WhiF56) Δ −89.34 (MTW) σ_c 4 (to In^{114}) 8 (to In^{114m}) (GoldmDT64)			
In^{113m}	99.8 m (GleG64) 104 m (LawJL40) 103 m (GirR58) others (BarnS39a, CatR65)	☢ IT (BarnS39a) Δ −88.95 (LHP, MTW)	A chem, excit, genet (BarnS39a) daughter Sn^{113} (BarnS39a)	γ In X-rays, 0.393 (64%) e^- 0.365, 0.389	daughter Sn^{113} (GirR58, BarnS39a)
In^{114}	72 s (LawJL37, BarnS39a)	☢ β^- 98%, EC 1.9%, β^+ 0.004% (GrodL56) β^+ 0.0039% (DzhB57c) Δ −88.58 (MTW)	A excit (ChanW37, BotW37, LawJL37) n-capt, sep isotopes (GoldhM48a) daughter In^{114m} (GoldsG50)	β^- 1.988 max β^+ 0.42 max γ Cd X-rays, 1.299 (0.17%)	daughter In^{114m} (GoldsG50) In^{113}(n, γ) (GoldhM48a)
In^{114m}	50.0 d (WriH57) 50.1 d (CaliJ59) others (BendW58, BoeF49a, HoffK57, BarnS39a, MaiF49, LawJL40)	☢ IT 96.5%, EC 3.5% (GrodL56) Δ −88.39 (LHP, MTW)	A chem, n-capt, excit (LawJL37, MitA38) parent In^{114} (GoldsG50)	γ In X-rays, 0.192 (17%), 0.558 (3.5%), 0.724 (3.5%) e^- 0.164, 0.188 daughter radiations from In^{114}	In^{113}(n, γ) (LawJL37, MitA38, MaiF49)
In^{115}	6 x 10^{14} y sp act (MarteE50) 5.1 x 10^{14} y sp act (WatD62a) 7 x 10^{14} y sp act (BearG61a) others (CohS51)	☢ β^- (MarteE50, CohS51) % 95.77 (WhiJ48) 95.67 (WhiF56) Δ −89.54 (MTW) σ_c 45 (to In^{116}) 154 (to In^{116m_1}) 4 (to In^{116m_2}) (GoldmDT64)	A chem, sep isotopes (MarteE50)	β^- 0.48 max γ no γ	
In^{115m}	4.50 h (DunwJ47) 4.53 h (LawJL40) 4.48 h (SalS65)	☢ IT 95%, β^- 5% (LangeL52a) Δ −89.21 (LHP, MTW)	A chem, excit (GoldhM38) daughter Cd^{115} (GoldhM38, CorkJ39, NisY40, MetR51a, WahA52, LangeL52a)	β^- 0.83 max e^- 0.308, 0.331 γ In X-rays, 0.335 (50%)	Cd^{114}(n, γ) Cd^{115}(β^-) (GoldhM38, SehM62) In^{115}(n, n') (GoldhM38, CohS48) In^{115}(p, p') (BarnS39a, BarnS39) In^{115}(α, α') (LarK39)
In^{116}	13.4 s (DomF60) 14.0 s (DucA60) 14.5 s (CapP57) 15.6 s (BrzJ65) 13 s (AmaE35, CorkJ39, WilhZ53, LawJL37)	☢ β^- (LawJL37) Δ −88.20 (MTW)	A n-capt (AmaE35) excit, n-capt (LawJL37)	β^- 3.3 max γ 0.434 (0.12%), 0.95 (0.1%), 1.293 (1.2%)	In^{115}(n, γ) (AmaE35, LawJL37, SerL47b)

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$_{49}$In^{116m_1}	54.0 m (LocE53, GravA47) 53.9 m (SilL51, DomF60) 55.1 m (CapP57) 57 m (BrzJ65)	☢ β^- (LawJL37) no IT, lim 0.5% (ColaJ60) Δ -88.14 (LHP, MTW)	A chem, n-capt (AmaE35) chem, excit, n-capt (LawJL37)	β^- 1.00 max γ 0.138 (3%), 0.417 (36%), 0.819 (17%), 1.09 (53%), 1.293 (80%), 1.508 (11%), 2.111 (20%)	In^{115}(n, γ) (AmaE35, MitA38a, SerL47b, HumV51, BolH64)
In^{116m_2}	2.16 s (AlexKF63) 2.2 s (HecP61) 2.5 s (AlexKF60, FetP62a) 2.3 s (WhiW62)	☢ IT (AlexKF60, FetP62a) Δ -87.98 (LHP, MTW)	A n-capt, sep isotopes (AlexKF60, HecP61, FetP62a) excit, sep isotopes, cross bomb (WhiW62)	γ In X-rays, 0.164 e^- 0.138, 0.160	In^{115}(n, γ) (AlexKF60, HecP61, FetP62a, WhiW62, AlexKF63)
In^{117}	45 m (NeedJ63, BrzJ65) 38 m (DudN61) 43 m (WolfeJ61) others (MGinC55, CoryC53)	☢ β^- (MGinC55) Δ -88.93 (MTW)	A chem, genet (CoryC53) daughter Cd^{117m}, daughter Cd^{117} (TanC66, CoryC53) not parent Sn^{117m}, lim 1% (MGinC55) daughter In^{117m} (MGinC55)	β^- 0.74 max e^- 0.132 γ Sn X-rays, 0.158 (87%), 0.565 (100%)	Cd^{116}(n, γ)Cd$^{117, 117m}$ (β^-), daughter Cd^{117m} (TanC66a)
In^{117m}	1.93 h (DudN61, Brz. 65) 1.96 h (NeedJ63) 1.90 h (MGinC55, MetR51b) 1.95 h (LawJL40) others (WolfeJ61, CoryC53)	☢ IT 47%, β^- 53% (TanC66b) IT 28%, β^- 72% (WolfeJ61) IT 22%, β^- 78% (MGinC55) Δ -88.61 (LHP, MTW)	A chem, excit (CorkJ39) daughter Cd^{117}, daughter Cd^{117m} (TanC66, MGinC55) parent In^{117} (MGinC55)	β^- 1.78 max e^- 0.286 γ In X-rays, 0.158 (14%), 0.314 (31%) daughter radiations from In^{117}	Cd^{116}(n, γ)Cd$^{117, 117m}$ (β^-) (TanC66a)
In^{118}	5.7 s (BrzJ65) 5.0 s (KantJ64a) 5.1 s (GleC61)	☢ β^- (CoryC53) Δ -87.5 (MTW)	B genet (CoryC53) chem, genet energy levels (GleC61) excit, sep isotopes (KantJ64a) daughter Cd^{118} (CoryC53, GleC61)	β^- 4.2 max γ 1.230 (15%)	daughter Cd^{118} (CoryC53, GleC61) Sn^{118}(n, p) (KantJ64a)
In^{118}	4.35 m (KantJ64a) 4.5 m (WilhZ53, DufR49a) 4.7 m (MeyP65) 4.9 m (BrzJ65)	☢ β^- (DufR49a) Δ -87.4 (KantJ64a, MTW)	B excit, sep isotopes (DufR49a) excit, sep isotopes, genet energy levels (KantJ64a) not daughter Cd^{118} (CoryC53, GleC61)	β^- 2.0 max γ 0.69 (41%), 1.05 (80%), 1.230 (97%), 2.04 (3%)	Sn^{118}(n, p) (KantJ64a)
In^{119}	2.1 m (KuoC60) 2.0 m (GleC61a) 2.3 m (YutH60) 2.8 m (BrzJ65)	☢ β^- (KuoC60, YutH60, GleC61a) Δ -87.6 (MTW)	B sep isotopes, excit (KuoC60, YutH60) chem, genet (GleC61a) daughter In^{119m} (GleC61a) daughter 2.7 m Cd^{119} (GleC61a)	β^- 1.6 max γ 0.82 (95%)	Sn^{120}(γ, p) (KuoC60, YutH60) daughter In^{119m}, fission (GleC61a)
In^{119m}	17.5 m (KuoC60) 18 m (DufR49a, GleC61a) 22.6 m (BrzJ65)	☢ β^- 95%, IT 5% (GleC61a) Δ -87.3 (LHP, MTW)	B chem, excit, sep isotopes (DufR49a) parent In^{119} (GleC61a) daughter 10 m Cd^{119} (NusN57, GleC61a) daughter 2.7 m Cd^{119} (GleC61a)	β^- 2.7 max γ [In X-rays, Sn L X-rays], 0.024, 0.30, 0.91 (doublet) daughter radiations from In^{119}	Sn^{120}(γ, p) (DufR49b, KuoC60) fission (GleC61a)
In^{120}	3.2 s (KantJ64a) 3 s (PouA60)	☢ β^- (KantJ64a) Δ -86 (KantJ64a, MTW)	B sep isotopes, cross bomb (PouA60)	β^- 5.6 max γ 1.171 (15%)	Sn^{120}(n, p) (PouA60, KantJ64a) Sb^{123}(n, α) (PouA60)
In^{120}	44 s (KantJ64a) 48 s (MeyP65) 50 s (PouA60) ≈55 s (MGinC58)	☢ β^- (PouA60) Δ -85.8 (KantJ64a, MTW)	B excit (MGinC58) sep isotopes, genet energy levels (PouA60)	β^- 3.1 max γ 0.090 (12%), 0.198 (9%), 0.71 (12%), 0.86 (34%), 0.94 (12%), 1.02 (61%), 1.171 (100%), 1.28 (14%), 1.47 (6%), 1.87 (7%), 2.01 (6%)	Sn^{120}(n, p) (MGinC58, PouA60, KantJ64a)
In^{121}	30 s (YutH60)	☢ [β^-] (YutH60) Δ -86 (MTW)	C excit, sep isotopes (YutH60)	γ 0.94	Sn^{122}(γ, p) (YutH60)
In^{121}	3.1 m (YutH60, WeisH65a)	☢ β^- (YutH60) Δ -86 (MTW)	C excit, sep isotopes (YutH60)	β^- 3.7 max	Sn^{122}(γ, p) (YutH60)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C 0), Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{49}$In$^{(121?)}$	11.5 m (NusN57)	☢ β$^-$ (NusN57)	G chem, genet (NusN57) daughter 3.5 m Cd$^{(121?)}$ (NusN57) Assignment probably incorrect (NDS, YutH60)	γ 0.85	deuterons on Sn (NusN57)
In$^{(121?)}$	32 m (NusN57)	☢ β$^-$ (NusN57)	G chem, genet (NusN57) daughter 3.5 m Cd$^{(121?)}$ (NusN57) Assignment probably incorrect (NDS, YutH60)	γ 0.52	deuterons on Sn (NusN57)
In^{122}	8 s (KantJ63a)	☢ β$^-$ (KantJ63a) Δ −83 (MTW)	B sep isotopes, genet energy levels (KantJ63a)	β$^-$ 5 max γ 0.99, 1.14	Sn^{122}(n, p) (KantJ63a)
In^{123}	36 s (YutH60)	☢ β$^-$ (YutH60) Δ −83 (MTW)	E excit, sep isotopes (YutH60)	β$^-$ 4.6 max	Sn^{124}(γ, p) (YutH60)
In^{123}	10 s (YutH60)	☢ [β$^-$] (YutH60) Δ −83 (MTW)	F excit, sep isotopes (YutH60) May be identical to 8 s In^{122} (LHP)	γ 1.1	Sn^{124}(γ, p) (YutH60)
In^{124}	≈3.6 s (KarrM64)	☢ β$^-$ (KarrM64) Δ −81 (MTW)	B sep isotopes, genet energy levels (KarrM64)	β$^-$ 5 max γ 0.99 (↑ 3), 1.13 (↑ 10), 3.21 (↑ 3)	Sn^{124}(n, p) (KarrM64)
$_{50}$Sn^{108}	9.2 m (HahR65) 9 m genet (MeaS55)	☢ [EC] (MeaS55)	A genet (MeaS55) chem, excit (HahR65) parent 39 m In^{108} (MeaS55)	γ In X-rays, 0.28, 0.42 daughter radiations from 39 m In^{103}	Cd^{106}(α, 2n) (HahR65)
Sn^{109}	18.1 m (PetrM56a)	☢ EC, β$^+$ (PetrM56a)	B chem, genet (PetrM56a) ancestor In^{109}, parent In^{109m1} (PetrM56a)	β$^+$ 1.6 max e$^-$ 0.305, 0.491, 0.86, 1.09 γ In X-rays, 0.335, 0.521, 0.89, 1.12 daughter radiations from In^{109m1}, In^{109}	Cd^{106}(α, n) (PetrM56a)
Sn^{110}	4.0 h (MeaS55, MGinC51) 4.5 h (MallE49)	☢ EC (MallE49)	A chem, sep isotopes (MallE49) chem, genet (MeaS55, NaiT64) parent 67 m In^{110}, not parent 4.9 h In^{110} (MeaS55, NaiT64)	γ In X-rays, 0.283 (95%) e$^-$ 0.255 daughter radiations from 67 m In^{110}	In^{115}(p, 6n) (NaiT64) Cd^{108}(α, 2n) (MeaS55, MallE49)
Sn^{111}	35.0 m (HinR49) 35 m (MGinC51, SnyJ65)	☢ EC 73%, β$^+$ 27% (SnyJ65) EC 71%, β$^+$ 29% (MGinC51) Δ −85.6 (MTW)	A chem, sep isotopes (HinR49) excit, cross bomb (SnyJ65)	β$^+$ 1.51 max γ In X-rays, 0.511 (54%, $\gamma^{\pm}$), 0.75 (1.1%), 0.97 (0.7%), 1.14 (1.8%), 1.54 (0.5%), 1.59 (0.6%) (0.9%), 1.89 (1.0%), 2.11 (0.3%), 2.32 (0.2%) daughter radiations from In^{111}	Cd^{110}(α, 3n) (MGinC51)
Sn^{112}		% 0.95 (BaiK50) Δ −88.64 (MTW) σ$_c$ 0.9 (to Sn^{113}) 0.4 (to Sn^{113m}) (GoldmDT64)			
Sn^{113}	115 d (GleG64) 118 d (CorkJ51f) 119 d (AviP56) 130 d (GardG56) others (DesY53, BarnS39a)	☢ EC, no β$^+$ (BarnS39a) Δ −88.32 (MTW)	A chem, excit (BarnS39a, LivJ39b) parent In^{113m} (BarnS39a)	γ In X-rays, 0.255 (1.8%) daughter radiations from In^{113m}	Sn^{112}(n, γ) (NelC50, CorkJ51f, SerL47b, BoweJ51) In^{113}(p, n) (BarnS39a) In^{113}(d, 2n) (ColeK47, GirR58)
Sn^{113m}	20 m (SchmM61) 27 m (SelI60)	☢ IT 91%, EC 9%, no β$^+$, lim 10^{-3}% (SchmM61) Δ −88.24 (LHP, MTW)	A chem, genet (SelI60) crit abs (SchmM61) daughter Sb^{113} (SelI60)	γ Sn X-rays, In X-rays, 0.079 (0.6%) e$^-$ 0.050, 0.075	Sn^{112}(n, γ) (SchmM61) Sn^{112}(d, n)Sb^{113}(EC), Sn^{114}(p, 2n)Sb^{113}(EC) (SelI60, SelI59)
Sn^{114}		% 0.65 (BaiK50) Δ −90.57 (MTW)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{50}Sn^{115}$		% 0.34 (BaiK50) Δ −90.03 (MTW)			
Sn^{116}		% 14.24 (BaiK50) Δ −91.523 (MTW) σ_c 0.006 (to Sn^{117m}) (GoldmDT64)			
Sn^{117}		% 7.57 (BaiK50) Δ −90.392 (MTW)			
Sn^{117m}	14.0 d (CorkJ51f, MihJ50)	☢ IT (MallE50) Δ −90.075 (LHP, MTW)	A chem (LivJ39b) chem, sep isotopes, cross bomb (MallE50) not daughter In^{117} (MGinC55)	γ Sn X-rays, 0.158 (87%) e^- 0.130, 0.155	$Sn^{116}(n,\gamma)$ (MihJ50) $Cd^{114}(\alpha,n)$ (LivJ39b)
Sn^{118}		% 24.01 (BaiK50) Δ −91.652 (MTW) σ_c 0.01 (to Sn^{119m}) (GoldmDT64)			
Sn^{119}		% 8.58 (BaiK50) Δ −90.062 (MTW)			
Sn^{119m}	≈250 d (MihJ50)	☢ IT (MihJ50) Δ −89.973 (LHP, MTW)	A chem, n-capt, sep isotopes (MihJ50)	γ Sn X-rays, 0.024 (16%) e^- 0.020, 0.026, 0.061	$Sn^{118}(n,\gamma)$ (MihJ50, NelC50, SchaG51a, BoweJ51)
Sn^{120}		% 32.97 (BaiK50) Δ −91.100 (MTW) σ_c 0.14 (to Sn^{121}) ≈0.001 (to Sn^{121m}) (GoldmDT64)			
Sn^{121}	27.5 h (NelC50) 27 h (MajN63) others (LeeJ49, LivJ39b)	☢ β^- (LivJ39b) Δ −89.21 (MTW)	A chem, excit (LivJ39b) chem, sep isotopes (LindnM48) descendant 13 s Cd^{121} (WeisH65)	β^- 0.383 max	$Sn^{120}(n,\gamma)$ (LeeJ49, DufR49c, NelC50, LivJ39b, SerL47b) $Sb^{123}(d,\alpha)$ (LindnM50a)
Sn^{121m}	76 y (FlyK65a) ≈25 y (DroB62)	☢ β^- (NelC50) Δ −89.14 (LHP, MTW)	D sep isotopes, n-capt (NelC50) chem (DroB62)	β^- 0.42 max e^- [0.007, 0.033] γ Sb X-rays, 0.037	$Sn^{120}(n,\gamma)$ (NelC50, SnyR65) fission (DroB62)
Sn^{122}		% 4.71 (BaiK50) Δ −89.943 (MTW) σ_c 0.001 (to Sn^{123}) 0.2 (to Sn^{123m}) (GoldmDT64)			
Sn^{123}	125 d (CorkJ51f) 130 d (LeeJ49, LeadG51) 126 d (NelC50) 136 d (GrumW46)	☢ β^- (LeadG51) Δ −87.80 (MTW)	A chem (LeadG46, LeadG51) chem, sep isotopes, cross bomb (LeeJ49)	β^- 1.42 max γ 1.08 ? (weak)	$Sn^{122}(n,\gamma)$ (LeeJ49, NelC50)
Sn^{123m}	39.5 m (DufR49c) 40 m (LivJ39b, LeeJ49, NelC50, MajN63) 41.5 m (MocD48)	☢ β^- (LivJ39b) Δ −87.78 (LHP, MTW)	A chem (LivJ39b) chem, sep isotopes, excit (LeeJ49, NelC50)	β^- 1.26 max e^- [0.130] γ Sb X-rays, 0.160 [84%]	$Sn^{122}(n,\gamma)$ (SerL47b, DufR49c, LeeJ49, NelC50) $Sn^{124}(n,2n)$ (PoolM37, LeeJ49)
Sn^{124}	$t_{1/2}$ ($\beta\beta$) $>2 \times 10^{17}$ y sp act (KalkM52, FireE52, HogB52)	% 5.98 (BaiK50) Δ −88.237 (MTW) σ_c 0.004 (to Sn^{125}) 0.1 (to Sn^{125m}) (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{50}$Sn^{125}	9.4 d (NelC50) 10.0 d (LeeJ49)	☢ β⁻ (LivJ39b) Δ −85.93 (MTW)	A chem (LivJ39b) chem, excit, sep isotopes (LeeJ49) chem, sep isotopes, n-capt, genet (NelC50) parent Sb^{125} (NelC50)	β⁻ 2.34 max γ 0.342 (0.3%), 0.468 (0.4%), 0.811 (1.5%), 0.904 (1.4%), 1.068 (4%), 1.17 (0.14%), 1.41 (0.14%), 1.97 (0.6%), 2.23 (0.05%) daughter radiations from Sb^{125}	Sn^{124}(n, γ) (LeeJ49, NelC50, LivJ39b, SerL47b)
Sn^{125m}	9.5 m (NelC50) 9.8 m (LeeJ49) 9.7 m (MajN63)	☢ β⁻ (LivJ39b) Δ −85.91 (LHP, MTW)	A chem, excit, n-capt (LivJ39b) chem, sep isotopes (DufR50a, LeeJ49)	β⁻ 2.04 max γ 0.325 (97%)	Sn^{124}(n, γ) (LeeJ49, NelC50, DufR50a, LivJ39b, SerL47b)
Sn^{126}	≈10^{5} y yield (DroB62)	☢ [β⁻] (DroB62) Δ −86 (MTW)	B chem, genet (DroB62) parent 19 m Sb^{126}, ancestor 12.5 d Sb^{126} (DroB62)	γ 0.060, 0.067, 0.092	fission (DroB62)
Sn^{126}	~50 m yield (BarnJ51)	☢ β⁻ (BarnJ51)	G chem, genet (BarnJ51) reassigned to Sn^{128} (DroB62)		fission (BarnJ51)
Sn^{127}	2.05 h (CarmH56) 2.10 h (UhlJ62) 2.2 h (DroB62, HageE62) others (DMarP62, MajN63)	☢ β⁻ (BarnJ51) Δ −84 (MTW)	A chem, genet (BarnJ51, CarmH56, DroB62, HageE62) chem, mass spect (UhlJ62) parent Sb^{127} (BarnJ51, CarmH56, DroB62, HageE62)	β⁻ 1.45 max ? γ 0.44, 0.49, 0.82, 1.10, 2.00, 2.32, 2.58, 2.68, 2.82 daughter radiations from Sb^{127}	fission (BarnJ51, DroB62, HageE62, UhlJ62) Te^{130}(n, α) (CarmH56, MajN63)
Sn^{127}	4.1 m (KauP65) 4.6 m genet (HageE62) ≈2.5 m genet (DroB62)	☢ β⁻ (KauP65) Δ −83.5 (KauP65, MTW)	A chem, genet (HageE62, DroB62) chem, sep isotopes (KauP65) parent Sb^{127} (HageE62, DroB62)	β⁻ 2.7 max γ 0.49 (100%)	fission (HageE62, DroB62) Te^{130}(n, α) (KauP65)
Sn^{128}	59 m (UhlJ62) 57 m (FranI55, HageE62) 62 m (DMarP62) 58 m (DroB62)	☢ β⁻ (DMarP62) Δ −83.4 (MTW)	A chem, genet (FranI55, HageE62, DroB62) chem, mass spect (UhlJ62) parent 11 m Sb^{128} (FranI55, DroB62, HageE62, UhlJ62, DMarP62) ancestor 9 h Sb^{128} (≈3%) (FranI56, DroB62) not ancestor 9 h Sb^{128}, lim 5% (HageE62)	β⁻ 0.80 max γ Sb X-rays, 0.044 (7%), 0.072 (19%), 0.50 (61%), 0.57 (22%) daughter radiations from 11 m Sb^{128}	fission (FranI55, DroB62, HageE62, DMarP62, UhlJ62)
Sn^{129}	9 m genet (HageE62) 6 m (DroB62)	☢ [β⁻] (HageE62, DroB62)	B chem (DroB62) chem, genet (HageE62) parent Sb^{129} (HageE62)	γ 1.15, others daughter radiations from Sb^{129}	fission (HageE62, DroB62)
Sn^{129}	1.0 h genet (HageE62)	☢ [β⁻] (HageE62)	B chem, genet (HageE62) parent Sb^{129} (HageE62)	daughter radiations from Sb^{129}	fission (HageE62)
Sn^{130}	2.6 m (PapA56)	☢ [β⁻] (PapA56)	D chem, genet (PapA56) parent 7 m Sb^{130} (PapA56, DroB62) not parent 35 m Sb^{130}, lim 10% (DroB62)	daughter radiations from 7.1 m Sb^{130}	fission (PapA56, FranI55, DroB62)
Sn^{131}	3.4 m (PapA56) <2 m (DroB62)	☢ [β⁻] (PapA56)	E chem, genet (PapA56) activity not observed (DroB62) parent Sb^{131} (PapA56)		fission (PapA56)
Sn^{132}	2.2 m genet (PapA56)	☢ [β⁻] (PapA56)	B chem, genet (PapA56) parent Sb^{132} (PapA56)		fission (PapA56)
$_{51}$Sb^{112}	0.9 m (SelI59)	☢ β⁺, EC (SelI59)	B chem, excit (SelI59)	γ Sn X-rays, 0.511 (γ$^{\pm}$), 1.27	Sn^{112}(p, n) (SelI59)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C¹²=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{51}$Sb^{113}	6.4 m (PatA62) 7 m (SelI58, SelI59)	☢ EC, β^+ (SelI58, SelI59, SelI60) Δ −83.85 (MTW)	A chem (RhoA57) chem, excit, sep isotopes cross bomb (SelI60, SelI59, SelI58) excit, sep isotopes (PatA62) parent Sn^{113m} (SelI60)	β^+ 2.42 max γ Sn X-rays, 0.32, 0.511 ($\gamma^{\pm}$), 0.6–0.9 (complex), 1.03, 1.2 (complex), 1.52 ? daughter radiations from Sn^{113m}	Sn^{112}(d, n) (SelI58, SelI60, RhoA57) Sn^{114}(p, 2n) (SelI59)
Sb^{114}	3.3 m (SelI59)	☢ β^+, EC (SelI59) Δ −84.3 (MTW)	B chem, excit, sep isotopes (SelI59)	β^+ 2.7 max γ Sn X-rays, 0.9, 1.30	Sn^{114}(p, n), Sn^{115}(p, 2n) (SelI59)
Sb^{115}	31 m (SelI58, SelI59) 36 m (FinR61) 32 m (SehM62)	☢ EC 67%, β^+ 33% (VarN63) EC 65%, β^+ 35% (SelI60) EC 88%, β^+ 12% (SehM62) Δ −87.00 (MTW)	A chem (RhoA57) chem, sep isotopes, excit, cross bomb (SelI58, SelI59, SelI61) chem, mass spect (FinR61) daughter Te^{115} (SelI60a, ReisR65)	β^+ 1.51 max γ Sn X-rays, 0.499 (100%), 0.511 (67%, $\gamma^{\pm}$), 0.98 (5%), 1.24 (5%), 2.22 (1%)	Sn^{114}(d, n) (SelI58, SelI61) Sn^{116}(p, 2n) (SelI59) In^{113}(α, 2n) (SehM62)
Sb^{116}	16 m (StahP53a) 14 m (AteA54) 15 m (KuzM58)	☢ EC 72%, β^+ 28% (FinR61) Δ −87.0 (MTW)	A chem, excit (StahP53a) genet (FinR61) daughter Te^{116} (FinR61)	β^+ 2.3 max γ Sn X-rays, 0.511 ($\gamma^{\pm}$, 56%), 0.93 (26%), 1.293 (85%), 2.23 (14%)	daughter Te^{116} (FinR61) In^{115}(α, 3n) (AteA54)
Sb^{116m}	60 m (TemG49, AteA54)	☢ EC 81%, β^+ 19% BolH64a) Δ −86.5 (LHP, MTW)	A chem, excit, mass spect (TemG49) not daughter Te^{116} (FinR61)	β^+ 1.16 max e^- 0.070, 0.095, 0.111 γ Sn X-rays, 0.099 (30%), 0.140 (30%), 0.406 (36%), 0.511 (38%, $\gamma^{\pm}$), 0.545 (68%), 0.96 (75%), 1.06 (27%), 1.293 (100%)	In^{115}(α, 3n) (TemG49) In^{113}(α, n) (JensB60)
Sb^{117}	2.8 h (FinR61, ColeK47, TemG49, KuzM58)	☢ EC 97.4%, β^+ 2.6% (MGinC55) EC 97.7%, β^+ 2.3% (BaskK64) Δ −88.57 (MTW)	A chem (LivJ39) chem, excit, mass spect (TemG49) daughter Te^{117} (FinR61)	β^+ 0.57 max γ Sn X-rays, 0.158 (87%), 0.511 (5%, $\gamma^{\pm}$)	In^{115}(α, 2n) (TemG49)
Sb^{117m}	1.6 × 10^{-4} s delay coinc (GhoA63)	☢	F crit abs [illegible]oA63) same as 0.726 level of Sn^{115}?	γ 0.080 (↑ 10), 0.17 (↑ 8), 0.24 (↑ 9), 0.46 (↑ 24) scint spect (GhoA63)	protons on Sb (GhoA63) not produced by protons on Sn (GritV65a)
Sb^{118}	3.5 m (LindnM48, FinR61) 3.6 m (RisJ40)	☢ EC, β^+ (FinR61) Δ −87.96 (MTW)	A excit (RisJ40) chem (LarK39) genet (FinR61, LindnM48) daughter Te^{118} (LindnM48, LindnM50a, FinR61)	β^+ 2.67 max γ Sn X-rays, 0.511 (150%, $\gamma^{\pm}$), 0.83 (0.4%), 1.230 (3%, doublet)	daughter Te^{118} (LindnM48a, FinR61) In^{115}(α, n) (LarK39, RisJ40)
Sb^{118m_1}	5.1 h (ColeK47, TemG49)	☢ EC 99+%, β^+ 0.16% (BolH61) no β^+, lim 0.1% (JensB60) Δ −87.77 (LHP. MTW)	A chem, cross bomb (ColeK47) chem, excit, mass spect (TemG49) not daughter Te^{118} (FinR61)	γ Sn X-rays, 0.041 (29%), 0.254 (93%), 1.049 (100%), 1.230 (100%) e^- 0.012, 0.036, 0.223	In^{115}(α, n) (ColeK47, TemG49, BolH61, RamasM61a, BodE62a)
Sb^{118m_2}	0.87 s (WhiW62)	☢ [IT] (WhiW62)	E excit (WhiW62)	γ 0.14 (↑ 4), 0.30 (↑ 10), 0.38 (↑ 10)	protons on Sb (WhiW62)
Sb^{119}	38.0 h (OlsJ57) others (ZaitN60a, ColeK47, LindnM48)	☢ EC (ColeK47) Δ −89.48 (MTW)	A chem, cross bomb (ColeK47) chem, genet energy levels (OlsJ57) daughter Te^{119m} (LindnM48, LindnM50a, FinR61) daughter Te^{119} (FinR61)	γ Sn X-rays, 0.024 (16%) e^- 0.020	Sb^{121}(p, 3n)Te^{119}(EC) (FinR61) Sn^{119}(p, n), Sn^{118}(d, n) (ColeK47)
Sb^{120}	15.89 m (EbrT65) 16.4 m (JohnH50) 16.6 m (PerlmM48, StahP53a) 17 m (HeyF37, LivJ38c)	☢ β^+, EC (BlasJ50) Δ −88.42 (MTW)	A chem, excit (BotW39, HeyF37, ChanW37) chem, excit, cross bomb (LivJ37)	β^+ 1.70 max γ Sn X-rays, 0.511 (87%, $\gamma^{\pm}$), 1.171 (1.3%)	Sn^{120}(p, n) (BlasJ50) Sn^{120}(d, 2n) (LindnM48) Sn^{119}(d, n) (LivJ39)
Sb^{120}	5.8 d (MGinC55a) 6.0 d (LindnM48)	☢ EC (LindnM48) no β^+ or IT, lim 0.3% (MGinC55a)	A chem, sep isotopes (LindnM48) chem, cross bomb (MGinC55a) chem, mass spect (JensB60)	γ Sn X-rays, 0.090 (81%), 0.200 (88%), 1.03 (99%), 1.171 (100%) e^- 0.061, 0.096, 0.171, 0.196	Sn^{119}(d, n) (JensB60) Sn^{120}(d, 2n) (LindnM48)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{51}Sb^{121}$		% 57.25 (WhiJ48) Δ −89.593 (MTW) σ_c 6 (to Sb^{122}) 0.06 (to Sb^{122m}) (GoldmDT64)			
Sb^{122}	2.80 d (BlasJ51a) 2.75 d (CorkJ54) 2.75 d (PerlmM58)	☢ β^- 97%, EC 3.0%, β^+ 0.006% (GlauM55, PerlmM58) β^- 97%, EC 3.1% (FarrB55) Δ −88.32 (MTW)	A chem (AmaE35) chem, cross bomb (LivJ39)	β^- 1.97 max β^+ 0.56 max γ Sn X-rays, 0.564 (66%), 0.686 (3.4%), 1.140 (0.7%), 1.26 (0.7%)	$Sb^{121}(n,\gamma)$ (AmaE35, LivJ39, SerL47b, HumV51)
Sb^{122m}	4.2 m (DMatE63, EngeR62) others (DMatE47, VanJ62)	☢ IT (DMatE47) no β^+, no β^-, lim 0.5% (DMatE62) Δ −88.16 (LHP, MTW)	A chem, n-capt, sep isotopes (DMatE47)	γ Sb X-rays, 0.061 (50%), 0.075 (17%) e^- 0.021, 0.030, 0.045, 0.056, 0.071	$Sb^{121}(n,\gamma)$ (DMatE51)
Sb^{123}	$t_{1/2}$ >1.3 × 10^{16} y sp act (WatD62a)	% 42.75 (WhiJ48) Δ −89.224 (MTW) σ_c 3.3 (to Sb^{124}) 0.03 (to Sb^{124m_1}) 0.015 (to Sb^{124m_2}) (GoldmDT64)			
Sb^{124}	60.4 d (MackR57a) 60.9 d (WriH57) 60.1 d (CaliJ59) 59.9 d (JohnCH58) others (BrzJ65)	☢ β^- (LivJ39) no EC, no β^+ (LangeL50c) Δ −87.58 (MTW) σ_c 2000 (GoldmDT64)	A chem (LivJ37) chem, excit, cross bomb (LivJ39)	β^- 2.31 max γ 0.603 (97%), 0.644 (7%), 0.72 (14%, doublet), 0.967 (2.4%), 1.048 (2.4%), 1.31 (3%, doublet), 1.37 (5%, doublet), 1.45 (2%), 1.692 (50%), 2.088 (7%)	$Sb^{123}(n,\gamma)$ (LivJ39, SerL47b)
Sb^{124m_1}	93 s (VanJ62a) 96 s (BrzJ63, BrzJ65) ≈78 s (DMatE47)	☢ IT 80%, β^- 20% (VanJ62a) Δ −87.57 (LHP, MTW)	A chem, n-capt, sep isotopes (DMatE47) genet energy levels (VanJ62a) daughter Sb^{124m_2} (VanJ62a)	β^- 1.19 max e^- 0.006, 0.009 γ Sb L X-rays, 0.505 (20%), 0.603 (20%), 0.644 (20%)	$Sb^{123}(n,\gamma)$ (VanJ62a, DMatE47)
Sb^{124m_2}	21 m (VanJ62a, DMatE47, BrzJ65)	☢ IT (VanJ62a) Δ −87.55 (LHP, MTW)	A chem, n-capt, sep isotopes (DMatE47) genet (VanJ62a) parent Sb^{124m_1} (VanJ62a)	e^- 0.021, 0.024 γ Sb L X-rays daughter radiations from Sb^{124m_1}	$Sb^{123}(n,p)$ (VanJ62a, DMatE57)
Sb^{125}	2.71 y (FlyK65a) 2.78 y (WyaE61) 2.6 y (KlehE60) 2.0 y (LazN56a) others (LeadG51a)	☢ β^- (CamG51) Δ −88.28 (MTW) σ_c <20 (GoldmDT64)	A chem (LivJ39) chem, n-capt (StanIC51) daughter Sn^{125} (NelC50) parent Te^{125m} (FrieG48, KerB49)	β^- 0.61 max e^- 0.004, 0.030, 0.144, 0.395 γ Te X-rays, 0.176 (6%), 0.427 (31%), 0.463 (10%), 0.599 (24%, doublet), 0.634 (11%), 0.66 (3%, doublet) daughter radiations from Te^{125m}	$Sn^{124}(n,\gamma)Sn^{125}(\beta^-)$ (SiegK49, FrieG48, StanIC51)
Sb^{126}	12.5 d (DroB62) others (GrumW46, BarnJ51)	☢ β^- (DroB62) Δ −86.3 (MTW)	B chem, genet (DroB62) descendant Sn^{126} (DroB62)	β^- 1.9 max γ 0.41, 0.69 (complex, 3 γ rays)	fission, descendant Sn^{126} (DroB62)
Sb^{126}	19.0 m (DroB62) 19 m (FranI56a, FranI58)	☢ β^- (FranI56a) β^-, [IT] (DroB62)	B chem (FranI56a) chem, sep isotopes (FranI58) chem, genet (DroB62) daughter Sn^{126} (DroB62)	β^- 1.9 max γ 0.41, 0.67 (complex, 2 γ rays)	$Te^{126}(n,p)$ (FranI56a, FranI58) fission, daughter Sn^{126} (DroB62)
Sb^{126}	9 h (BarnJ51)	☢ β^- (BarnJ51)	G chem, excit (BarnJ51) reassigned to Sb^{128} (DroB62)		fission (BarnJ51)
Sb^{127}	93 h (DroB62, SeiJ51b) 94 h (UhlJ62) 88 h (BosH57) 95 h (GrumW46) others (AbeP39)	☢ β^- (AbeP39) Δ −86.70 (MTW)	A chem, genet (AbeP39) chem, mass spect (UhlJ62) parent Te^{127} (AbeP39, GleL51h) parent Te^{127} (84%), parent Te^{127m} (16%) (BeydJ48) daughter 2.1 h Sn^{127} (BarnJ51, CarmH56, DroB62, HageE62) daughter 4 m Sn^{127} (HageE62, DroB62)	β^- 1.5 max γ 0.060, 0.25, 0.41, 0.46, 0.68, 0.77, 0.92, 1.10, 1.34 daughter radiations from Te^{127}, Te^{127m}	fission, daughter Sn^{127} (AbeP39, SleN51b, GrumW46, BarnJ51, DroB62, UhlJ62, KatcS48)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}≡0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{51}$Sb$^{?}$	6.2 d (BosH57)	☢ (BosH57)	G chem (BosH57) activity is probably a mixture of Sb^{126} (12.5 d) and Sb^{127} (LHP)		fission (BosH57)
Sb^{128}	10.8 m (DMarP62) 10.1 m (DroB62) 10.3 m (FranI56, BrzJ63) 10.7 m (HageE62) others (UhlJ62, BarnJ51, BrzJ65)	☢ β^- (FranI55) Δ −84.7 (MTW)	A chem (FranI56) chem, sep isotopes, genet energy levels (HageE62) chem, mass spect (UhlJ62) daughter Sn^{128} (FranI55, DroB62, HageE62, UhlJ62, DMarP62)	β^- 2.6 max γ 0.320 (83%), 0.75 (200%, doublet), 1.07 (4%)	fission, daughter Sn^{128} (FranI55, DroB62, HageE62, UhlJ62, DMarP62) Te^{128}(n, p) (HageE62, BrzJ63)
Sb^{128}	8.6 h (UhlJ62) 8.9 h (DroB62) 9.6 h (FranI56, BrzJ65) 9.9 h (HageE62)	☢ β^- (FranI56)	A chem (FranI56) chem, sep isotopes, genet energy levels (HageE62) chem, mass spect (UhlJ62) descendant Sn^{128} (FranI56, DroB62) not descendant Sn^{128} (HageE62)	β^- 1 max γ 0.314, 0.53, 0.64, 0.75 (complex)	fission (FranI55, UhlJ62) Te^{128}(n, p) (HageE62)
Sb^{129}	4.3 h (UhlJ62) 4.2 h (DroB62, AbeP39, VasiI58)	☢ β^- (AbeP39) Δ −85 (MTW)	A chem, genet (AbeP39) chem, mass spect (UhlJ62) parent Te^{129} (AbeP39) daughter 9 m Sn^{129}, daughter 1.0 h Sn^{129} (HageE62)	β^- 1.87 max γ 0.073, 0.34, 0.460, 0.540, 0.81, 0.91, 1.04, 1.24 daughter radiations from Te^{129}	fission (AbeP39, KatcS48, DroB62, HageE62, UhlJ62)
Sb^{130}	33 m (HageE62) 36 m (BrzJ63, BrzJ65) 37 m (DroB62) others (BarnJ62)	☢ β^- (BarnJ52) Δ −82 (MTW)	A chem, excit (fission yield) (BarnJ52) chem, sep isotopes (HageE62, BrzJ63) chem, genet energy levels (DroB62) not daughter Sn^{130}, lim 10% (DroB62)	γ 0.19, 0.33, 0.82 (complex), 0.94	Te^{130}(n, p) (HageE62, BrzJ63) fission (BarnJ52, DroB62)
Sb^{130}	7.1 m (HageE62) 6 m (DroB62) 10 m (BarnJ52) 12 m (BrzJ65)	☢ β^- (BarnJ52) Δ −82 (MTW)	A chem (PapA56, BarnJ52) chem, sep isotopes (HageE62, BrzJ63) chem, genet energy levels (DroB62) daughter Sn^{130} (PapA56, DroB62)	γ 0.20, 0.82 (complex), 1.03, 1.16	Te^{130}(n, p) (HageE62, BrzJ63) fission (BarnJ52, DroB62) daughter Sn^{130} (PapA56, DroB62)
Sb^{131}	26 m (CoopJ64, UhlJ62, DMarP62) 23 m (PapA51) others (CookG51)	☢ β^- (PapA51)	A chem, genet (PapA51, CookG51) parent Te^{131}, parent Te^{131m} (PapA51, CookG51) parent Te^{131} (93%), parent Te^{131m} (7%) (SaraD65) daughter Sn^{131} (PapA56)	γ 0.64 (37%), 0.95 (48%) daughter radiations from Te^{131}, Te^{131m}	fission (PapA51, CookG51, CoopJ64)
Sb^{132}	2.1 m (PapA56) others (AbeP39, CookG51)	☢ β^- (AbeP39)	B chem, genet (AbeP39) parent Te^{132} (AbeP39) daughter Sn^{132} (PapA56)		fission (AbeP39, PapA56, CookG51)
Sb^{133}	4.2 m (CookG51) 4.4 m (PapA51)	☢ β^- (PapA51)	B chem, genet (PapA51) parent Te^{133m} (PapA51)		fission (PapA51, CookG51)
Sb^{134}	<1.5 s (BemC64)		F genet (activity not observed) (BemC64)		fission (BemC64)
Sb$^{134?}$	≈50 s (PapA51) 45 s (CookG51)	☢ β^- (PapA51)	G chem (PapA51) not ancestor I^{134}, may be an isomer of Sb^{132} (BemC64)		fission (PapA51, CookG51)
Sb^{135}	2 s genet (BemC64)	☢ [β^-] (BemC64)	B chem, genet (BemC64) ancestor I^{135} (BemC64)		fission (BemC64)
$_{52}$Te^{107}	2.2 s (MacfR65)	☢ a (MacfR65)	B excit, cross bomb, sep isotopes (MacfR65)	a 3.28	Ru^{96}(O^{16}, 5n) (MacfR65)
Te^{108}	5.3 s (MacfR65)	☢ a (MacfR65) [β^+, EC], p (SiiA65)	B excit, cross bomb, sep isotopes (MacfR65, SiiA65)	a 3.08 p 2.6 (broad peak), 3.4, 3.7	Ru^{196}(O^{16}, 4n) (MacfR65, SiiA65)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}≡0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{52}$Te$^{(<113)}$	16 m (RhoA57)	☢ β^+, [EC] (RhoA57)	F chem (RhoA57)		alphas on Sn (RhoA57)
Te^{115}	6.0 m (ReisR65) 6 m (SelI60a) 5–6 m (FinR61)	☢ β^+ ≈80%, EC ≈20% (ReisR65) Δ −82.5 (ReisR65, MTW)	B chem, excit, sep isotopes, genet (SelI60a, ReisR65) parent Sb^{115} (SelI60a, ReisR65)	β^+ 2.8 max γ Sb X-rays, 0.511 (160%, $\gamma^\pm$), 0.72 (34%), 0.96 (6%), 1.08 (24%), 1.28 (32%), 1.38 (32%), 1.58 (6%) daughter radiations from Sb^{115}	Sn^{112}(α, n) (SelI60a, ReisR65)
Te$^{114,115?}$	1.4 h (RhoA57)	☢ β^+, [EC] (RhoA57)	F chem (RhoA57) may be Te^{116} + Sb^{116} (+ Te^{117}?) (LHP)	γ 0.10 (?), 0.12 (?), 0.511 ($\gamma^\pm$), 0.75, 1.0 (?), 1.3 (?)	alphas on Sn (RhoA57)
Te$^{?}$	8 h (RhoA57)	☢	F chem (RhoA57)	γ 0.67	alphas on Sn (RhoA57)
Te^{116}	2.50 h (FinR61) others (LindnM48, KuzM58)	☢ EC, β^+ (?) (FinR61) β^+ (LindnM48) no α, lim 1 x 10^{-7}% (KarrM63) Δ −85.4 (MTW)	A chem (LindnM48) chem, mass spect (FinR61) parent Sb^{116} (FinR61) not parent Sb^{116m} (FinR61)	γ Sb X-rays, 0.094 e^- 0.063, 0.089 β^+ 0.44 max (?) daughter radiations from Sb^{116}	protons on Sb (FinR61, LindnM48, KuzM58)
Te^{117}	61 m (FinR61) 65 m (KhuD62) 66 m (VarN61, ButeF65a)	☢ EC 70%, β^+ 30% (FinR61, KhuD62) no α, lim 0.005% (KarrM63) Δ −85.1 (MTW)	A chem, mass spect (FinR61) parent Sb^{117} (FinR61) daughter 14.5 m I^{117} (ButeF65a)	β^+ 1.81 max γ Sb X-rays, 0.511 (60%, $\gamma^\pm$), 0.72 (65%), 0.93 (6%), 1.78 (9%) daughter radiations from Sb^{117}	Sn^{114}(α, n) (VarN61, KhuD62) protons on Sb (FinR61)
Te^{117}	1.9 h (ButeF65a)	☢ β^+ (ButeF65a)	E chem, decay charac (ButeF65a) daughter 14.5 m I^{117} (ButeF65a)	β^+ 1.7 max	daughter 14.5 m I^{117} (ButeF65a)
Te^{118}	6.00 d (FinR61) others (LindnM48, AndeG65)	☢ EC (LindnM48) no α, lim 2 x 10^{-6}% (KarrM63) Δ −88 (MTW)	A chem (LindnM48) chem, mass spect (FinR61) parent Sb^{118} (LindnM48, LindnM50a, FinR61) not parent Sb^{118m_1} (FinR61) daughter I^{118} (ZaitN60a)	γ Sb X-rays daughter radiations from Sb^{118}	protons on Sb (FinR61) Sb^{121}(d, 5n) (LindnM48, LindnM50a)
Te^{119}	15.9 h (FinR61) others (ZaitN60, ZaitN60a, KocC60)	☢ EC (FinR61) β^+ 5% (KocC60) Δ −87.19 (MTW)	A chem, excit, sep isotopes (KocC60) chem, mass spect, genet (FinR61) parent Sb^{119} (FinR61) daughter I^{119} (ZaitN60, ZaitN60a)	β^+ 0.627 max γ Sb X-rays, 0.645 (85%), 0.70 (11%), 1.76 (3.6%) daughter radiations from Sb^{119}	Sb^{121}(p, 3n) (FinR61) Sn^{116}(α, n) (KocC60)
Te^{119m}	4.68 d (KantJ63) others (SorA60, FinR61, KocC60, ZaitN60, ZaitN60a, LindnM48)	☢ EC (LindnM48) β^+ ≤0.5% (KantJ63) no α, lim 4 x 10^{-5}% (KarrM63) Δ −86.9 (LHP, MTW)	A chem, genet (LindnM48) chem, genet, mass spect (FinR61) parent Sb^{119} (LindnM48, LindnM50a, FinR61)	γ Sb X-rays, 0.153 (62%), 0.270 (25%), 0.92–1.14 (36%, complex), 1.221 (67%), 2.09 (4%) e^- 0.122, 0.133, 0.148, 0.240, 0.266 daughter radiations from Sb^{119}	Sb^{121}(p, 3n) (FinR61) Sb^{121}(d, 4n) (LindnM48, LindnM50) Sn^{116}(α, n) (KocC60)
Te^{120}		% 0.089 (BaiK50) Δ −89.40 (MTW) σ_c 0.3 (to Te^{121}) 2.0 (to Te^{121m}) (GoldmDT64)			
Te^{121}	17 d (EdwJ46, ZaitN60a, BhaR63) others (BursS46)	☢ EC (EdwJ46) no β^+, lim 0.1% (ChuY64) Δ −88.31 (MTW)	A chem, genet (EdwJ46, BursS46) daughter Te^{121m} (BursS46) daughter I^{121} (MarqL50)	γ Sb X-rays, 0.508 (18%), 0.573 (80%) e^- 0.007, 0.033, 0.543	Sb^{121}(α, 4n)I^{121}(β^+) (MarqL50) Sb^{121}(d, 2n) (EdwJ46, AubR64) Sb^{121}(p, n) (EdwJ46, AubR64) Te^{120}(n, γ) (HillR49a, AubR64) daughter Te^{121m} (BursS46)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12} \equiv 0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{52}Te^{121m}$	154 d (HillR51, BhaR63) 143 d (EdwJ46) 125 d (SeaG40) 140 d (CorkJ51f)	☢ IT 90%, EC 10% (ChuY64) β^+ ≈0.003% (AubR64) Δ −88.01 (LHP, MTW)	A chem, excit, cross bomb (SeaG40) chem, n-capt, sep isotopes (CorkJ51f) parent Te^{121} (BursS46)	γ Te X-rays, Sb X-rays, 0.212 (82%), 1.10 (3%) e^- 0.007, 0.050, 0.077, 0.180 daughter radiations from Te^{121}	Sb^{121}(d, 2n) (SeaG40, EdwJ46, AubR64) Sb^{121}(p, n) (SeaG40, EdwJ46, AubR64) Te^{120}(n, γ) (CorkJ51f, AubR64)
Te^{122}		% 2.46 (BaiK50) Δ −90.29 (MTW) σ_c 2 (to Te^{123}) 1 (to Te^{123m}) (GoldmDT64)			
Te^{123}	$t_{1/2}$ (EC_K) 1.2 x 10^{13} y sp act (WatD62a) $t_{1/2}$ (EC) >10^{13} y sp act (HeiJ55)	☢ EC (WatD62a) % 0.87 (BaiK50) Δ −89.16 (MTW) σ_c 400 (GoldmDT64)	B chem (WatD62a)	γ Sb X-rays	
Te^{123m}	117 d (AndeG65) 104 d (HillR51) 121 d (CorkJ51f)	☢ IT (HillR49a) Δ −88.92 (LHP, MTW)	A chem, n-capt, sep isotopes (HillR49a)	γ Te X-rays, 0.159 (84%) e^- 0.057, 0.084, 0.127	Te^{122}(n, γ) (HillR49a, KatzR50, HammB51, CorkJ51f) Sb^{123}(d, 2n) (KatzR50)
Te^{124}		% 4.61 (BaiK50) Δ −90.50 (MTW) σ_c 2 (to Te^{125}) 5 (to Te^{125m}) (GoldmDT64)			
Te^{125}		% 6.99 (BaiK50) Δ −89.03 (MTW) σ_c 1.5 (GoldmDT64)			
Te^{125m}	58 d (HillR51, AndeG65)	☢ IT (FrieG48) Δ −88.89 (LHP, MTW)	A chem, genet (FrieG48) daughter Sb^{125} (FrieG48, KerB49) not daughter I^{125}, lim 0.05% (FrieG51a)	e^- 0.004, 0.030, 0.078, 0.105 γ Te X-rays, 0.035 (7%), 0.110 (0.3%)	daughter Sb^{125} (FrieG48, KerB49) Te^{124}(n, γ) (HillR49a)
Te^{126}		% 18.71 (BaiK50) Δ −90.05 (MTW) σ_c 0.9 (to Te^{127}) 0.1 (to Te^{127m}) (GoldmDT64)			
Te^{127}	9.4 h (KniJD56, MajN63) 9.3 h (SeaG40, MangS62) 9.5 h (BonaG64)	☢ β^- (AbeP39) Δ −88.30 (MTW)	A chem (TapG38, AbeP39) chem, excit, cross bomb (SeaG40) daughter Te^{127m} (SeaG40, GleL51h, WilliRR51) daughter Sb^{127} (84%) (AbeP39, GleL51h, BeydJ48)	β^- 0.70 max γ I X-rays, 0.058 (0.010%), 0.21 (0.03%, doublet), 0.360 (0.05%), 0.417 (0.3%)	Te^{126}(n, γ), daughter Te^{127m} (SeaG40, SerL47b) fission (AbeP39, SeaG40, WilliRR48, GleL51h)
Te^{127m}	109 d (AndeG65) 105 d (KniJD56) 115 d (CorkJ51f) 90 d (SeaG40)	☢ IT 99.2%, β^- 0.8% (AubR65) IT 98%, β^- 2% (KniJD56) Δ −88.21 (LHP, MTW)	A chem, excit, genet (SeaG40) parent Te^{127} (SeaG40, GleL51h, WilliRR51) daughter Sb^{127} (16%) (BeydJ48)	γ Te X-rays, 0.059 (0.19%), 0.089 (0.08%), 0.67 (0.004%) e^- 0.057, 0.084 β^- [0.73 max] daughter radiations from Te^{127}	Te^{126}(n, γ) (HillR49a, SeaG40, SerL47b) fission (GrumW46, GleL51h, WilliRR48, GrumW48)
Te^{128}		% 31.79 (BaiK50) Δ −88.98 (MTW) σ_c 0.14 (to Te^{129}) 0.017 (to Te^{129m}) (GoldmDT64)			

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$_{52}$Te^{129}	68.7 m (BrzJ63, BrzJ65) 67 m (WafH48, MajN63) 72 m (SeaG40, BonaG64) 70 m (AbeP39, GleL51h, MangS62) 74 m (GravW56)	☢ β^- (SeaG40) Δ −87.02 (MTW)	A chem, excit (BotW39, SeaG40) daughter Te^{129m} (SeaG40, GrumW46, WilliRR51) daughter Sb^{129} (AbeP39)	β^- 1.45 max e^- 0.022, 0.026 γ I X-rays, 0.027 (19%), 0.275 (1.7%, doublet), 0.455 (15%), 0.81 (0.5%, complex), 1.08 (1.5%)	daughter Te^{129m} (SeaG40, GrumW46, WilliRR51) Te^{128}(n, γ) (MangS62, SeaG40, SerL47b) fission (AbeP39, HahO43a, GrumW46, WilliRR48, NoveT51a)
Te^{129m}	34.1 d (AndeG65) 33.5 d (CorkJ51f) 33 d (MajN63) 32 d (BrzJ65) others (SeaG40, NoveT51b, GravW56, WafH48)	☢ IT 64%, β^- 36% (DevaS64a) IT 68%, β^- 32% (AndeG62) Δ −86.92 (LHP, MTW)	A chem, genet (SeaG40) parent Te^{129} (SeaG40, GrumW46, WilliRR51)	β^- 1.60 max e^- 0.074, 0.102 γ Te X-rays, 0.69 (6%) daughter radiations from Te^{129}	Te^{128}(n, γ) (HillR49a, SeaG40, SerL47b) fission (HahO43a, GrumW46, WilliRR48, NoveT51b, PapA51a, GrumW48)
Te^{130}	$t_{1/2}$ ($\beta\beta$) 8×10^{20} y, Xe ratios, mass spect (TakaN65) 1×10^{21} y Xe ratios, mass spect (IngM50) others (FremJ52, SharmH53, FulH52)	% 34.49 (BaiK50) Δ −87.34 (MTW) σ_c 0.2 (to Te^{131}) 0.04 (to Te^{131m})			
Te^{131}	24.8 m (GeiK52) others (MangS62, SeaG40, AbeP39)	☢ β^- (SeaG40) Δ −85.16 (MTW)	A chem, excit (SeaG40) daughter Te^{131m} (AbeP39, SeaG40, WilliRR51) parent I^{131} (AbeP39, SeaG40, PapA51, CookG51, LivJ38e, HahO39c) daughter Sb^{131} (PapA51, CookG51, SaraD65)	β^- 2.14 max e^- 0.116, 0.144 γ I X-rays, 0.150 (68%), 0.453 (16%), 0.493 (5%), 0.603 (4%), 0.95 (3%, complex), 1.00 (4%, doublet), 1.147 (6%)	Te^{130}(n, γ) (SeaG40, SerL47b, GeiK52) daughter Te^{131m} (AbeP39, SeaG40, WilliRR51)
Te^{131m}	30 h (AbeP39, SeaG40)	☢ β^- 82%, IT 18% (BedeA61, DevaS65) β^- 78%, IT 22% (HebE55) Δ −84.98 (LHP, MTW)	A chem, genet (SeaG40) parent Te^{131} (AbeP39, SeaG40, WilliRR51) daughter Sb^{131} (CookG51, PapA51, SaraD65)	β^- 2.46 max (5%), 0.9 max e^- 0.048, 0.069, 0.149, 0.177 γ Te X-rays, I X-rays, 0.081 (2%), 0.102 (5%), 0.200 (8%), 0.241 (8%), 0.336 (9%), 0.78 (60%, complex), 0.85 (31%, doublet), 1.127 (13%), 1.206 (11%), 1.629 (3%), 1.860 (1%), 1.965 (2%) daughter radiations from Te^{131} I^{131}	Te^{130}(n, γ) (SeaG40, SerL47b) fission (SaraD65, AbeP39, HahO39c, KatcS51d, WilliRR51, PapA51a)
Te^{132}	77.7 h (PapA51a) 78 d (AndeG65) others (AbeP39, CheeG58, FleW56, HahO39b)	☢ β^- (AbeP39) Δ −85.21 (MTW)	A chem, genet (AbeP39) fission fragment range (KatcS48) parent I^{132} (AbeP39, HahO39c, HahO39b, NoveT51a, WinsW51) daughter Sb^{132} (AbeP39)	β^- 0.22 max e^- 0.020, 0.048, 0.197 γ I X-rays, 0.053 (17%), 0.230 (90%) daughter radiations from I^{132}	fission (AbeP39, HahO39a, HahO39b, PapA51a, KatcS48)
Te^{133}	12.5 m (PruS65)	☢ [β^-] (PruS65)	B chem, genet (PruS65) daughter Te^{133m}, parent I^{133} (PruS65)	γ 0.15, 0.31, 0.41, 0.73, 1.02, 1.33, 1.71, 1.85	fission, daughter Te^{133m} (PruS65, SaraD65)
Te^{133m}	50 m (FergJ62) 63 m (PapA52) 53 m (AlvT57) 60 m (AbeP39, WuC40)	☢ β^- 87%, IT 13% (AlvT57)	A chem, genet (AbeP39) parent 12.5 m Te^{133} (PruS65) daughter Sb^{133} (PapA51) ancestor I^{133} (AbeP39, HahO39c, SegE40, WuC40, WuC45, PapA51)	β^- 2.4 max e^- 0.303 γ Te X-rays, 0.31 (21%), 0.432 (50%), 0.47 (22%), 0.557 (35%), 0.63 (18%), 0.70 (24%), 0.754 (85%), 0.91 (57%), 1.01 (10%), 1.33, 1.71, 1.85 daughter radiations from I^{133} daughter radiations from Te^{133} included in above listing	fission (AbeP39, HahO39c, SegE40, WuC40, PapA51, KatcS48, SaraD65)
Te^{133}	2 m (PapA52)	☢ β^- (PapA52)	G chem, genet (PapA52) activity not observed (PruS65)		daughter Te^{133m} (PapA52)
Te^{134}	42 m (FergJ62) 44 m (PapA51a) 43 m (AbeP39)	☢ β^- (AbeP39)	A chem, genet (AbeP39) parent I^{134} (AbeP39, HahO39c, PapA51a) others (KatcS48, PolA40a)	γ I X-rays, 0.08 (13%), 0.17 (16%), 0.204 (21%), 0.262 (19%) daughter radiations from I^{134}	fission (KatcS48, HahO39c, AbeP39, PolA40a, PapA51a, FergJ62)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{52}$Te^{135}	<2 m (GleL51i, DodR40, KatcS51f)	☢ β^- (DodR40)	E genet (DodR40) parent I^{135} (GleL51i, KatcS51f)		fission (GleL51i, DodR40, KatcS51f)
Te$^?$	≈1 m (HahO43a)	☢ β^- (HahO43a)	E chem (HahO43a)		fission (HahO43a)
$_{53}$I^{117}	7 m (AndeG65)	☢ β^+ (AndeG65), [EC]	C mass spect, [chem] (AndeG65)	γ 0.16, 0.34, 0.522 ($\gamma^{\pm}$)	protons on La (AndeG65)
I^{117}	14.5 m genet (ButeF65a)	☢ [β^+] (ButeF65a)	F chem, genet (ButeF65a) parent 61 m Te^{117}, parent 1.9 h Te^{117} (ButeF65a)		protons on I (ButeF65a)
I^{118}	13.9 m (AndeG65) 17 m (ZaitN60a, ButeF65a) others (AagP57)	☢ β^+ ≈54%, EC ≈46% (AndeG65) Δ −81 (ButeF65a, AndeG65, MTW)	B mass spect (AagP57) chem, genet (ZaitN60a) parent Te^{118} (ZaitN60a) daughter Xe^{118} (AndeG65)	γ Te X-rays, 0.511 (108%, $\gamma^{\pm}$), 0.55, 0.60, 1.15	protons on I (ZaitN60a, ButeF65a)
I^{119}	19.5 m (AndeG65) 18 m (RosG54) 21 m genet (ZaitN60, ZaitN60a) 19 m (AagP57) 26 m (ButeF65a)	☢ β^+ 51%, EC 49% (AndeG65)	A chem (MarqL50) mass spect (AagP57) chem, genet (ZaitN60, ZaitN60a) parent Te^{119} (ZaitN60, ZaitN60a) daughter Xe^{119} (AndeG65)	γ Te X-rays, 0.26, 0.511 (102%, $\gamma^{\pm}$), 0.78 daughter radiations from Te^{119}, Sb^{119}	N^{14} on Pd (RosG54) protons on I (ZaitN60, ZaitN60a)
I^{120}	1.35 h (AndeG65) 1.30 h (ButeF65) 1.4 h (AagP57)	☢ EC 54%, β^+ 46% (AndeG65) Δ −83.8 (ButeF65, AndeG65, MTW)	A mass spect, chem (AagP57, AndeG65) chem, genet (ButeF65) daughter Xe^{120} (ButeF65)	β^+ 4.0 max γ Te X-rays, 0.511 (92%, $\gamma^{\pm}$), 0.56, 0.62, 1.52	protons on I, daughter Xe^{120} (ButeF65)
I^{120}	30 m (MarqL50, KuzM58a)	☢ β^+ (MarqL50)	G chem (MarqL50, KuzM58a) activity not observed (AndeG65)		alphas on Sb (MarqL50) protons on I (KuzM58a)
I^{121}	2.12 h (AndeG65) 2.0 h (AagP57, ButeF65) 1.5 h (MathH54a, DroB52) 2.1 h (ZaitN60) 1.4 h (RosG54) 1.8 h (MarqL50, KuzM58a)	☢ EC 91%, β^+ 9% (AndeG65) Δ −86.0 (MTW)	A chem, genet (MarqL50) mass spect (AagP57) parent Te^{121} (MarqL50) daughter Xe^{121} (MathH54a, DroB52)	β^+ 1.2 max γ Te X-rays, 0.212 (90%), 0.27 (3%), 0.32 (6%), 0.511 (18%, $\gamma^{\pm}$)	Sb^{121}(α, 4n) (MarqL50)
I^{122}	3.5 m (MathH54a) 3.4 m (DroB52) 3.6 m (YouJ51) 4 m (MarqL50)	☢ β^+ (MarqL50), [EC] Δ −86.15 (MTW)	A chem, excit (MarqL50) sep isotopes (YouJ51) daughter Xe^{122} (TilDE52, DroB52)	β^+ 3.1 max γ Te X-rays, 0.511 [130%, $\gamma^{\pm}$], 0.564, 0.69, 0.78	Sb^{121}(α, 3n) (MarqL50) Te^{122}(p, n) (YouJ51)
I^{123}	13.3 h (AndeG65) 13.0 h (MitA49a) 13 h (MarqL50, MathH54a, KuzM58a)	☢ EC (MarqL50) no β^+ (MitA59) Δ −88 (MTW)	A chem, excit (MarqL50) chem, sep isotopes (MitA49a) daughter Xe^{123} (DroB52, MathH54a, TilDE52)	γ Te X-rays, 0.159 (83%) e^- 0.127	Sb^{121}(α, 2n) (MarqL50, MitA49a, MitA59, GupR60b)
I^{124}	4.15 d (AndeG65) 4.2 d (DysN58, MitA59) 4.1 d (GirR59g) 4.0 d (LivJ38e) 4.5 d (MarqL50) 3.4 d (AagP57)	☢ EC 74%, β^+ 26% (DysN58) EC 75%, β^+ 25% (GirR59g) EC 71%, β^+ 29% (MitA59) no β^-, lim 0.1% (MerC61) EC(K)/EC(L) 9 (MitA59) Δ −87.33 (MTW)	A chem, excit, cross bomb (LivJ38e)	β^+ 2.14 max γ Te X-rays, 0.511 (50%, $\gamma^{\pm}$), 0.605 (67%), 0.644 (12%), 0.73 (14%), 1.37 (3%), 1.51 (4%), 1.69 (14%), 2.09 (2.0%), 2.26 (1.5%)	Sb^{121}(α, n) (MarqL50, LivJ38e) Sb^{123}(α, 3n) (MarqL50)
I^{125}	60.2 d (LeuH64, GleG64) 60.0 d (FrieG51a) 57.4 d (MatthC60) others (KuzM58a, ReidA46a)	☢ EC, no β^+ (ReidA46a, GleL47) EC(L+M+...)/EC(K) 0.254 (LeuH64) Δ −88.88 (MTW) σ_c 900 (GoldmDT64)	A chem (ReidA46a) chem, excit (GleL47) genet (BergI51c) daughter Xe^{125} (BergI51c) not parent Te^{125m}, lim 0.05% (FrieG51a)	γ Te X-rays, 0.035 (7%) e^- 0.004, 0.030	Sb^{123}(α, 2n) (MarqL50) daughter Xe^{125} (BergI51c) deuterons on Te (ReidA46a, GleL47, FleP58)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}≡0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{53}I^{126}$	12.8 d (AndeG65) 13.3 d (PerlmM54) 13.0 d (LivJ38e) 13.1 d (MocD48, AagP57)	☢ EC 55%, β^- 44%, β^+ 1.3% (PerlmM54), EC 55%, β^- 44%, β^+ 1.2% (KoerL55) EC(K) 51% (EroJ57a) Δ -87.90 (MTW)	A chem (TapG38) chem, excit, cross bomb (LivJ38e)	β^- 1.25 max β^+ 1.13 max γ Te X-rays, 0.386 (34%), 0.667 (33%)	Sb^{123}(α, n) (LivJ38e, MarqL50) Te^{125}(d, n) (LivJ38e) Te^{126}(p, n) (DubL40a)
I^{126}	2.6 h (AagP57)		G mass spect (AagP57) activity not observed (NaraV65)		fission (AagP57)
$\underline{I^{127}}$		% 100 (NierA37a) Δ -88.984 (MTW) σ_c 6.4 (GoldmDT64)			
I^{128}	24.99 m (HulO41) others (AagP57, LivJ38e)	☢ β^- 93.6%, EC 6.4% (BencN56) β^+ 3 x 10^{-3}% (LanghH61b) Δ -87.71 (MTW)	A chem, n-capt (AmaE35)	β^- 2.12 max γ Te X-rays, 0.441 (14%), 0.528 (1.4%), 0.743 (0.2%), 0.969 (0.3%)	I^{127}(n, γ) (AmaE35, TapG38, SerL47b, SiegK46c, OrsA49, HumV51)
I^{129}	1.7 x 10^7 y sp act (KatcS51k) others (PurB56)	☢ β^- (KatcS47) Δ -88.50 (MTW) σ_c 28 (GoldmDT64)	A chem, n-capt (KatcS47) chem, mass spect (KatcS51k)	β^- 0.150 max e^- 0.005, 0.034 γ Xe X-rays, 0.040 (9%)	fission (KatcS47, KatcS51k)
I^{130}	12.3 h (AndeG65) 12.5 h (AagP57) 12.6 h (LivJ38e)	☢ β^- (LivJ38e) Δ -86.89 (DanH65, MTW) σ_c 18 (GoldmDT64)	A chem, cross bomb (LivJ38e) chem, mass spect (AagP57)	β^- 1.7 max (0.4%), 1.04 max γ 0.419 (35%), 0.538 (99%), 0.669 (100%), 0.743 (87%), 1.15 (12%)	I^{129}(n, γ) (SmiW59) Te^{130}(d, 2n) (LivJ38e) Te^{130}(p, n) (GarvH58b) Cs^{133}(n, α) (WuC40)
I^{131}	8.05 d (BurkL58, BarthR53, GleG64) 8.07 d (KeeJ58, SelH53) 8.06 d (LocE53) 8.14 d (SreJ51a) 8.04 d (SinW51)	☢ β^- (LivJ38e) Δ -87.441 (MTW) σ_c ≈0.7 (GoldmDT64)	A chem (LivJ38e) chem, genet (SeaG40) daughter Te^{131} (LivJ38e, AbeP39, HahO39c, SeaG40, PapA51, CookG51) parent Xe^{131m} (≈1%) (BrosA49, BergI50c)	β^- 0.806 max (0.6%), 0.606 max average β^- energy: 0.19 ion ch (CaswR52) e^- 0.046, 0.330 γ Xe X-rays, 0.080 (2.6%), 0.284 (5.4%), 0.364 (82%), 0.637 (6.8%), 0.723 (1.6%) daughter radiations from Xe^{131m}	fission (AbeP39, HahO39c, GrumW46, SulW51g, YafL47, GrumW48, FinB51c)
I^{132}	2.26 h (EmeE54) 2.34 h (AndeG65) 2.30 h (WahA55) 2.5 h (WillaD62) others (AagP57, AbeP39, HahO39b)	☢ β^- (AbeP39) Δ -85.71 (MTW)	A chem, genet (AbeP39) chem, mass spect (AagP57) daughter Te^{132} (AbeP39, HahO39c, HahO39b, NoveT51a, WinsW51)	β^- 2.12 max γ 0.24 (1%), 0.52 (20%, complex), 0.67 (144%, complex), 0.773 (89%), 0.955 (22%), 1.14 (6%, doublet), 1.28 (7%), 1.40 (14%, complex), 1.45 (1%), 1.91 (1.3%), 1.99 (1.3%)	daughter Te^{132}, from fission (AbeP39, HahO39c, HahO39b, NoveT51a, WinsW51)
I^{133}	20.3 h (AndeG65) 20.8 h (KatcS53) 20.9 h (WahA55) 20.5 h (VasiI58) 22.4 h (PapA51a)	☢ β^- (AbeP39, HahO39c) Δ -85.9 (MTW)	A chem (AbeP39) chem, genet (WuC40) descendant Te^{133m} (AbeP39, HahO39c, SegE40, WuC40, WuC45, PapA51) daughter 12.5 m Te^{133} (PruS65) parent Xe^{133} (SegE40, WuC40, WuC45) parent Xe^{133m} (2.4%) (ZelH51, KetB51a)	β^- 1.27 max γ 0.53 (90%) daughter radiations from Xe^{133}, Xe^{133m}	fission (AbeP39, HahO39c, SegE40, WuC40, PapA51, SulW51h, FinB51c, HolmG59)
I^{134}	52.0 m (AndeG65) 52.8 m (JohnN61) 52.5 m (PapA51a) 52.4 m (WahA55) others (AbeP39, AagP57)	☢ β^- (AbeP39) Δ -84.0 (MTW)	A chem (AbeP39) fission fragment range (KatcS48) chem, mass spect (AagP57) daughter Te^{134} (HahO39c, AbeP39, PapA51a)	β^- 2.43 max γ 0.135 (3%), 0.41 (8%, complex), 0.55 (8%), 0.61 (18%), 0.85 (95%), 0.89 (65%), 1.07 (1.4%), 1.15 (10%), 1.46 (4%), 1.62 (5%), 1.79 (5%)	fission (YafL47, HahO39c, AbeP39, PolA40a, PolA40, LidL49, KatcS51e, PapA51a, KatcS48, FinB51c)
I^{135}	6.68 h (PeaW47a) 6.7 h (GleL51i, KatcS51f) 6.8 h (WahA55) others (DodR40)	☢ β^- (WahA55) Δ -84 (MTW)	A chem, genet (DodR40, SegE40) parent Xe^{135m} (30%), parent Xe^{135} (70%) (PeaW47a) daughter Te^{135} (GleL51i, KatcS51f) descendant Sb^{135} (BemC64) others (SegE40, DodR40, GotH40, WuC45, BallN51h, WuC40, FinB51c, AagP57)	β^- 1.4 max γ 0.42 (7%), 0.86 (11%), 1.04 (9%), 1.14 (37%), 1.28 (34%), 1.46 (12%), 1.72 (19%), 1.80 (11%) daughter radiations from Xe^{135m}, Xe^{135}	fission (SegE40, WuC40, DodR40, WuC45, PeaW47a, GleL51i, KatcS51f, FinB51c)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
${}_{53}I^{136}$	83 s (JohnN59) 86 s (StanlC49) others (StraF40)	☢ β^- (StraF40) Δ −79.4 (MTW)	B chem (StraF40) chem, decay charac (JohnN59)	β^- 7.0 max (≤6%), 5.6 max γ 0.20 (12%), 0.27 (18%), 0.39 (19%), 1.32 (95%, complex), 2.3 (19%, complex), 2.63 (10%), 2.8 (8%), 3.2 (5%)	fission (StraF40, SeeW43, StanlC49, JohnN59)
I^{137}	22.0 s (n) (HugD48) 24.4 s (n) (PerloG59) 22.5 s (n) (RedW47) 19.3 s genet (SugaN49) others (CoxS58, KeeG57, SneA47a)	☢ β^-, β^-n (≈6%) (LeviJ51)	A chem (StraF40) chem, genet (SeeW43, SugaN49) parent Xe^{137} (SeeW43, SugaN49)	n average energy 0.6 daughter radiations from Xe^{137}	fission (StraF40, SeeW43, RedW47, SugaN49, HugD48, PerloG59, SneA47a, SugaN47)
I^{138}	5.9 s (SugaN49) others (PerloG59, KeeG57)	☢ β^- (SugaN49) n (KeeG57, PerloG59)	B chem, genet (SugaN49) ancestor Cs^{138} (SugaN49)		fission (SugaN49, PerloG59, KeeG57)
I^{139}	2.7 s (SugaN49) 2.0 s (PerloG59, CoxS58)	☢ β^- (SugaN49) n (PerloG59, CoxS58)	B chem, genet (SugaN49) parent Xe^{139}, ancestor Ba^{139} (SugaN49)	daughter radiations from Xe^{139}	fission (SugaN49, CoxS58, PerloG59)
${}_{54}Xe^{118}$	6 m (AndeG65)	☢ β^+, [EC] (AndeG65)	B chem, mass spect (AndeG65) parent I^{118} (AndeG65)	γ 0.05, 0.511 ($\gamma^\pm$) daughter radiations from I^{118}	protons on La (AndeG65)
Xe^{119}	6 m (AndeG65)	☢ β^+, [EC] (AndeG65)	B chem, mass spect (AndeG65) parent I^{119} (AndeG65)	γ [I X-rays], 0.10, 0.511 ($\gamma^\pm$) daughter radiations from I^{119}	protons on La (AndeG65)
Xe^{120}	40 m (AndeG65) 43 m (ButeF65)	☢ [EC] (AndeG65)	A chem, mass spect (AndeG65) chem, genet (ButeF65) parent I^{120} (ButeF65)	γ I X-rays, 0.055, 0.073, 0.176, 0.76 daughter radiations from I^{120}	protons on I (ButeF65)
Xe^{121}	39 m (AndeG65) 40 m (DroB52, MooR60, MathH54a) others (TilDE52, ButeF65)	☢ β^+ (MathH54a), [EC] Δ −82.2 (MTW)	A chem, genet (DroB52, TilDE52) chem, mass spect (AndeG65) parent I^{121} (MathH54a, DroB52)	β^+ 2.8 max γ [I X-rays], 0.080, 0.096, 0.132, 0.437, 0.511 ($\gamma^\pm$) daughter radiations from I^{121}	I^{127}(p, 7n) (TilDE52, DroB52, MooR60)
Xe^{122}	20.1 h (AndeG65) 19.5 h (TilDE52) 18.5 h (MooR60) 20.0 h (DroB52) 19 h (MathH54a)	☢ EC (MathH54a)	A chem, genet (TilDE52, DroB52, MathH54a) chem, mass spect (AndeG65) parent I^{122} (TilDE52, DroB52)	γ I X-rays, 0.060, 0.090, 0.110, 0.148, 0.180, 0.345 e^- 0.058, 0.116 daughter radiations from I^{122}	I^{127}(p, 6n) (TilDE52, DroB52)
Xe^{123}	2.08 h (AndeG65) 1.85 (MooR60, ButeF65) 1.8 h (MathH54a, PreiI62) 1.7 h (DroB52) 2.1 h (TilDE52)	☢ EC, β^+ (MathH54a) Δ 85 (MTW)	A chem, genet (TilDE52, DroB52, MathH54a) chem, mass spect (AndeG65) parent I^{123} (TilDE52, DroB52, MathH54a) daughter Cs^{123} (MathH54a, MathH54, PreiI62)	β^+ 1.51 max e^- 0.115, 0.144, 0.295 γ I X-rays, 0.090, 0.110, 0.149, 0.178, 0.329, 0.511 ($\gamma^\pm$), 0.68, 0.90, 1.10 daughter radiations from I^{123}	I^{127}(p, 5n) (TilDE52, DroB52, MathH54a)
Xe^{124}		% 0.096 (NierA50a) Δ −87.5 (MTW) σ_c 110 (GoldmDT64)			
Xe^{125}	16.8 h (AndeG65) 18.0 h (BergI52) 17 h (MooR60) 20 h (AndeDL50)	☢ EC, no β^+ (BergI51c, AndeDL50) Δ −87 (MTW)	A chem, sep isotopes (AndeDL50) chem, mass spect (BergI51c) parent I^{125} (BergI51c) daughter Cs^{125} (MathH54)	γ I X-rays, 0.055, 0.188, 0.242 e^- 0.022, 0.050, 0.154, 0.182, 0.209 daughter radiations from I^{125}	I^{127}(p, 3n) (MooR60) Xe^{124}(n, γ) (BergI51c)
Xe^{125m}	55 s (MathH54) 60 s (MooR60)	☢ IT (?) (MathH54)	B genet (MathH54) daughter Cs^{125} (≈0.1%) (MathH54)	γ [Xe X-rays], 0.075, 0.111	daughter Cs^{125} (MathH54) I^{127}(p, 3n) (MooR60)
Xe^{126}		% 0.090 (NierA50a) Δ −89.15 (MTW) σ_c ≈2 (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{54}$Xe^{127}	36.41 d (BaleS54) others (BresM64, ForR58, CreEC40a, ArteK50, BergI51)	☢ EC, no β^+ (MathH55a, ForR58) Δ -88.54 (WintG65a, MTW)	A chem (CreEC40a) chem, sep isotopes (ArteK50) mass spect (BergI51a) daughter Cs^{127} (FinR50a)	γ I X-rays, 0.058 (1.4%), 0.145 (4.2%), 0.172 (22%), 0.203 (65%), 0.375 (20%) e^- 0.024, 0.112, 0.139, 0.170, 0.198	I^{127}(p, n) (CreEC40a, MathH55a, ForR58) I^{127}(d, 2n) (BaleS54, ForR58) Xe^{126}(n, γ) (CamM44, BergI51a)
Xe^{127m}	75 s (CreEC40a)	☢ IT (CreEC40a, MathH54)	B chem (CreEC40a) genet (MathH54) daughter Cs^{127} (0.01%) (MathH54)	γ Xe X-rays, 0.125, 0.175	I^{127}(p, n) (CreEC40a) daughter Cs^{127} (MathH54)
Xe^{128}		% 1.919 (NierA50a) Δ -89.85 (MTW) σ_c <5 (GoldmDT64)			
Xe^{129}		% 26.44 (NierA50a) Δ -88.692 (MTW) σ_c 25 (GoldmDT64)			
Xe^{129m}	8.0 d (BergI51a)	☢ IT (BergI51a) Δ -88.456 (LHP, MTW)	A chem, mass spect (BergI51a)	γ Xe X-rays, 0.040 (9%), 0.197 (6%) e^- 0.005, 0.034, 0.162, 0.191	Xe^{128}(n, γ) (BergI51a)
Xe^{130}		% 4.08 (NierA50a) Δ -89.88 (MTW) σ_c <5 (GoldmDT64)			
Xe^{131}		% 21.18 (NierA50a) Δ -88.411 (MTW) σ_c 85 (GoldmDT64)			
Xe^{131m}	11.8 d (AndeG65) 12.0 d (BergI50c, PerlmM53) others (BrosA49, CamM44)	☢ IT (BrosA49, CamM44) Δ -88.247 (LHP, MTW)	A chem (CamM44) chem, genet (BrosA49) mass spect (BergI50c) daughter I^{131} (≈1%) (BrosA49, BergI50c) not daughter Cs^{131} (CanR51b, SaraB54)	γ Xe X-rays, 0.164 (2%) e^- 0.129, 0.159	Xe^{130}(n, γ) (CamM44, BergI50c)
Xe^{132}		% 26.89 (NierA50a) Δ -89.272 (MTW) σ_c 0.2 (to Xe^{133}) <5 (to Xe^{133m}) (GoldmDT64)			
Xe^{133}	5.270 d (MacnJ50) 5.4 d (BergI52)	☢ β^- (DodR40) Δ -87.73 (MTW) σ_c 190 (GoldmDT64)	A chem (LangsA39, DodR40, SegE40) chem, excit (WuC40) mass spect (ThodH47, ThuS49) daughter I^{133} (SegE40, WuC40, WuC45)	β^- 0.346 max e^- 0.045, 0.075 γ Cs X-rays, 0.081 (37%)	fission (SegE40, DodR40, WuC40, BornH43a, WuC45, ThodH47, BehH51, EngeD51b) Xe^{132}(n, γ) (RieW43, AlvT58, ThieP62, BrowF61)
Xe^{133m}	2.26 d (ErmP61) 2.35 d (BergI52) 2.1 d (KetB51a) others (BergI51b)	☢ IT (KetB50a) Δ -87.50 (LHP, MTW)	A chem (KetB50a) mass spect (BergI51b) daughter I^{133} (2.4%) (ZelH51, KetB51a)	γ Xe X-rays, 0.233 (14%) e^- 0.198, 0.227 daughter radiations from Xe^{133}	fission (KetB51a, BergI50b) Xe^{132}(n, γ) (BergI51b, ErmP61)
Xe^{134}		% 10.4 (NierA50a) Δ -88.121 (MTW) σ_c 0.2 (to Xe^{135}) <5 (to Xe^{135m}) (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M A), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{54}$Xe^{135}	9.14 h (AndeG65) 9.13 h (BrowF53) 9.19 h mass spect (ClarW64) 9.2 h (NewA51, HoaE51c, BergI52, GleL51i) others (RieW43, DodR40, WuC40, ClanE41)	☢ β^- (SegE40) Δ −86.6 (MTW) σ_c 2.7 x 10^6 (GoldmDT64)	A chem (SegE40, DodR40) chem, excit (WuC40) mass spect (ThuS49) daughter I^{135} (70%) (PeaW47a) daughter Xe^{135m} (WuC45) parent Cs^{135} (SugaN49a) others (SegE40, DodR40, GotH40, RieW43, ClanE41, SeeW43a, BehH51)	β^- 0.92 max e^- 0.214 γ 0.250 (91%), 0.61 (3%)	Xe^{134}(n, γ) (RieW43) fission (SegE40, DodR40, BehH51) Ba^{138}(n, α) (WuC40, SeeW43a, WuC45)
Xe^{135m}	15.6 m (KotK60, RieW43) 15.8 m (AlvT60) 15.3 m (PeaW47a) others (NoveT51c)	☢ IT (WuC45) no β^-, lim 10% (AlvT60) Δ −86.1 (MTW, LHP)	A chem, genet (GotH40, WuC45) daughter I^{135} (30%) (PeaW47a) parent Xe^{135} (WuC45) others (GotH40, WuC45, RieW46, SeeW43a, ThodH47)	γ Xe X-rays, 0.527 (80%) e^- 0.493, 0.522 daughter radiations from Xe^{135}	daughter I^{135} (PeaW47a, GotH40, WuC45, AlvT60) Xe^{134}(n, γ) (RieW43) fission (GotH40, WuC45, ThodH47, KotK60, AlvT60) Ba^{138}(n, α) (SeeW43a)
Xe^{136}		% 8.87 (NierA50a) Δ −86.42 (MTW) σ_c 0.15 (GoldmDT64)			
Xe^{137}	3.9 m (SugaN49, OnegR64, HolmGB63) 3.8 m (SeeW43) 3.4 m (RieW43)	☢ β^- (SeeW43) Δ −82.8 (MTW)	A chem (SeeW43) mass spect (ThuS49) daughter I^{137} (SeeW43, SugaN49) parent Cs^{137} (TurA51, GleL51k)	β^- 4.1 max γ 0.455 (33%)	Xe^{136}(n, γ) (RieW43, SeeW43a, SugaN49) fission (SeeW43, SugaN49, GleL51k)
Xe^{138}	17.5 m (OckD62) 14.0 m (ClarW64) 17 m (GlasG40) others (HahO40, AndeG65)	☢ β^- (HahO39c) Δ −80.9 (NDS, MTW)	A chem (HahO39c) mass spect (ThuS49) parent Cs^{138} (HahO39c, HahO40, GlasG40, SeeW43a)	β^- 2.4 max γ 0.16 (↑ 33), 0.26 (↑ 100), 0.42 (↑ 40), 0.51 (↑ 8), 1.78 (↑ 66), 2.02 (↑ 58) daughter radiations from Cs^{138}	fission (HahO39c, HahO40, GlasG40, SeeW43a, ThuS49, ThuS55, NasS55)
Xe^{139}	43 s (OckD62) 41 s (DilC51a)	☢ β^- (HahO39c, HeyF39) Δ −76.5 (MTW)	A chem, genet (HahO39c, HeyF39) daughter I^{139} (SugaN49) parent Cs^{139} (HahO39c, HeyF39, HahO40a, HahO40) ancestor Ba^{139} (HahO39c, HeyF39, DilC51a)	γ 0.18 (↑ 41), 0.22 (↑ 100), 0.30 (↑ 57), 1.15 (↑ 23) daughter radiation from Cs^{139}	fission (HahO39c, HeyF39, HahO40a, HahO40, SugaN49, DilC51a, OckD62)
Xe^{140}	16.0 s (DilC51a) 10 s (OveR51) ≈15 s (OckD62) others (HahO40a)	☢ β^- (HahO40)	A chem, genet (HahO40) ancestor Ba^{140} (HahO40, DilC51, DilC51a, OveR51, BradE51)	γ 0.13 daughter radiations from Cs^{140}	fission (HahO40a, HahO40, DilC51, DilC51a, OveR51, BradE51, OckD62)
Xe^{141}	1.7 s (KatcS46, OveR51) 3 s (DilC51a)	☢ β^- (BradE51)	B chem, genet (BradE51) ancestor La^{141} (BradE51) ancestor Ce^{141} (DilC51, DilC51a, OveR51) ancestor Ba^{141} (BradE51, OveR51, DilC51a)		fission (BradE51, DilC51, DilC51a, OveR51)
Xe^{142}	≈1.5 s (WolfsK60)	☢ [β^-] (WolfsK60)	B chem, genet (WolfsK60) ancestor La^{142} (WolfsK60)		fission (WolfsK60)
Xe^{143}	1.0 s (DilC51a)	☢ β^- (BradE51)	B chem, genet (BradE51) ancestor Ce^{143} (BradE51, DilC51a)		fission (DilC51a, BradE51)
Xe^{144}	≈1 s (DilC51a)	☢ β^- (DilC51)	B chem, genet (DilC51) ancestor Ce^{144} (DilC51, DilC51a)		fission (DilC51, DilC51a)
$_{55}$Cs^{123}	8.0 m (PreiI62) 6 m (MathH54)	☢ β^+ (MathH54), [EC]	B chem, genet (MathH54, PreiI62) parent Xe^{123} (MathH54, MathH54a, PreiI62) daughter Ba^{123} (PreiI62)		In^{115}(C^{12}, 4n) (PreiI62) I^{127}(α, 8n) (MathH54)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{55}Cs^{125}$	45 m (MathH54) 49 m (PreiI62)	☢ EC 51%, β^+ 49% (FrieG62) Δ -84 (MTW)	A chem, mass spect (MathH54, MicM54) parent Xe^{125m} (≈0.1%), parent Xe^{125} (MathH54) daughter Ba^{125} (PreiI62) [descendant La^{125}] (PreiI63)	β^+ 2.05 max e^- 0.077, 0.107 γ Xe X-rays, 0.112, 0.511 (98%, $\gamma^\pm$) daughter radiations from Xe^{125} Xe^{125m}	$I^{127}(a, 6n)$ (MathH54) $In^{115}(N^{14}, 4n)Ba^{125}(\beta^+)$ (PreiI62)
Cs^{126}	1.6 m (KalkM54)	☢ β^+ 82%, EC 18% (KalkM54) Δ -84.4 (MTW)	A chem, mass spect (KalkM54) daughter Ba^{126} (KalkM54)	β^+ 3.8 max γ Xe X-rays, 0.386 (38%), 0.511 (164%, $\gamma^\pm$)	daughter Ba^{126} (KalkM54)
Cs^{127}	6.2 h (MathH54, PreiI63) 6.1 h (MicM54, NijG55) 5.5 h (FinR50a)	☢ EC 96.5%, β^+ 3.5% (FrieG62) Δ -86.4 (MTW, WintG65a)	A chem, mass spect (FinR50a, MicM54) parent Xe^{127} (FinR50a) parent Xe^{127m} (0.01%) (MathH54) daughter Ba^{127} (LindnM52, PreiI62) descendant La^{127} (YafL63)	γ Xe X-rays, 0.125 (10%), 0.406 (72%), 0.511 (7%, $\gamma^\pm$) e^- 0.090, 0.119, 0.371 β^+ 1.08 max daughter radiations from Xe^{127}	$I^{127}(a, 4n)$ (FinR50a, MicM54, MathH54)
Cs^{128}	3.8 m (LindnM52) 3.9 m (WapA53a) 3.5 m (FinR53) 2.5 m (MurA55)	☢ β^+ ≈51%, EC ≈49% (JhaS61) β^+ 75%, EC 25% (HollaJ55) Δ -85.92 (MTW)	B chem, genet (FinR51) daughter Ba^{128} (FinR51, LindnM52, HollaJ55) descendant La^{128} (YafL63)	β^+ 2.9 max e^- 0.407 γ Xe X-rays, 0.441 (27%), 0.511 110%, $\gamma^\pm$), 0.528, 0.576, 0.97 (1%), 1.12 (1%) See also γ's of Ba^{128}	daughter Ba^{128} (FinR51, LindnM52, HollaJ55)
Cs^{129}	32.1 h (SheraE65) 30.7 h (NijG55) 31 h (FinR50a)	☢ EC, no β^+ (FinR50a) Δ -88 (MTW)	A chem, mass spect (FinR50a, MicM54) daughter Ba^{129} (ThomC50, FinR50)	γ Xe X-rays, 0.040 (2%), 0.280 (3%), 0.320 (4%), 0.375 (48%), 0.416 (25%), 0.550 (5%) e^- 0.005, 0.034, 0.057, 0.336, 0.376	$I^{127}(a, 2n)$ (FinR50a, JhaS60a, NierW58) daughter Ba^{129} (ThomC50, FinR50)
Cs^{130}	30 m (SmiA52a, MicM54) others (FinR50a)	☢ β^+, EC, β^- (β^+/β^- 27.5) (SmiA52a) Δ -86.89 (MTW)	A chem, excit (SmiA52a) chem, mass spect (MicM54)	β^+ 1.97 max β^- 0.442 max γ Xe X-rays, 0.511 ($\gamma^\pm$)	$I^{127}(a, n)$ (FinR50a, SmiA52a, NierW58)
Cs^{131}	9.70 d (GleG64) 9.69 d (LarN60) others (LyoW63, YafL49, KatcS47a, YuF49, KondE50, JosB60)	☢ EC, no β^+ (FinB47, CanR51b, KondE50) Δ -88.06 (MTW)	A chem, genet (KatcS47a) chem, mass spect (KarrD49) daughter Ba^{131} (KatcS47a, YuF47, YafL49, CanR51b) not parent Xe^{131m} (CanR51b, SaraB54)	γ Xe X-rays	$Ba^{130}(n, \gamma)Ba^{131}(EC)$ (KatcS47a, YuF47, YafL49, CanR51b)
Cs^{132}	6.59 d (DeaP64) 6.54 d (RobiR62a) 6.48 d (WhyG60) others (CamM44)	☢ EC 97%, β^+ 0.6%, β^- 2% (RobiR62a, TayH63) β^+ 1.2% (JhaS61b) Δ -87.19 (MTW)	A chem, excit (CamM44) genet energy levels (BhaK56, RobiR62a)	β^+ 0.40 max β^- [0.7 max] γ Xe X-rays, 0.48 (4%, complex), 0.668 (99%), 1.138 (0.5%), 1.320 (0.6%)	$Cs^{133}(p, pn)$ (JhaS61b, RobiR62a, TayH63) $Xe^{132}(p, n)$ (NierW58) $Cs^{133}(n, 2n)$ (CamM44, LangeL51a)
Cs^{133}		% 100 (NierA37a, WhiF56) Δ -88.16 (MTW) σ_c 28 (to Cs^{134}) 2.6 (to Cs^{134m}) (GoldmDT64)			
Cs^{134}	2.046 y (DieL63) 2.05 y (EasH60) 1.99 y (FlyK65a) 2.07 y (WyaE61, GeiKW57) 2.19 y (MerW57) 2.26 y (EdwJ58) others (BayJ58, GleL51m, KalbD40, ScheiH38, SerL47b)	☢ β^- (KalbD40) no EC, lim 1% (KeiG55) no β^+, lim 0.009% (MimW51) Δ -86.79 (MTW) σ_c 136 (GoldmDT64)	A n-capt (AlexK38) chem, n-capt, excit (KalbD40)	β^- 0.662 max γ 0.57 (23%, complex), 0.605 (98%), 0.796 (99%, complex), 1.038 (1.0%), 1.168 (1.9%), 1.365 (3.4%)	$Cs^{133}(n, \gamma)$ (AlexK38, ScheiH38, KalbD40, SerL47b)
Cs^{134m}	2.895 h (KeiB61) 2.91 h (BaeA60, WarhH64) others (SlaH45, KalbD40, SerL47b)	☢ IT (GoldhM48a, CaldR50) β^- ≈1% (KeiG55) Δ -86.65 (MTW, LHP)	A chem, n-capt (AmaE35, MLenJ35a) chem, excit, n-capt (KalbD40)	γ Cs X-rays, 0.128 (14%) e^- 0.005, 0.009, 0.092, 0.122 β^- 0.55 max	$Cs^{133}(n, \gamma)$ (AmaE35, MLenJ35a, KalbD40, SerL47b)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{55}$Cs^{135}	3.0 x 10^{6} y sp act (ZelH49) 2.1 x 10^{6} y yield (SugaN49a)	☢ β^- (SugaN49a) Δ −87.8 (MTW) σ_c 8.7 (GoldmDT64)	A chem, genet (SugaN49a) chem, mass spect (IngM49) daughter Xe^{135} (SugaN49a)	β^- 0.21 max γ no γ	daughter Xe^{135} (SugaN49a) fission (ZelH49)
Cs^{135m}	53 m (WarhH62, HalleI64)	☢ IT (WarhH62) Δ −86.2 (MTW, LHP)	A chem, sep isotopes, cross bomb, crit abs (WarhH62) chem, mass spect (HalleI64)	γ Cs X-rays, 0.781 (100%), 0.840 (96%) e^- 0.745, 0.775, 0.804	Xe^{134}(d, n) (WarhH62) Xe^{132}(α, p) (WarhH62) Ba^{135}(n, p) (WarhH62) protons on Ba (HalleI64)
Cs^{136}	13.7 d (GleL49) 12.9 d (OlsJ54a) 13.5 d (WilleR60)	☢ β^- (GleL51l) Δ −86.6 (LHP, MTW)	A chem (GleL46, GleL51l) chem, excit (GleL49) chem, mass spect (OlsJ54a)	β^- 0.657 max (7%), 0.341 max e^- 0.116, 0.126, 0.158, 0.302 γ Ba X-rays, 0.067 (11%), 0.086 (6%), 0.16 (36%, complex), 0.273 (18%), 0.340 (53%), 0.818 (100%), 1.05 (82%), 1.25 (20%) daughter radiations from Ba^{136m} included in above listing	La^{139}(n, α) (CamM44, GleL49, BernsH61) Ba^{138}(d, α) (GirR59, GrabZ60b)
Cs^{137}	30.0 y (weighted average by FlyK65) 29.7 y (GorbS63) 30.4 y mass spect (FarrH61, DieL63) 29.2 y mass spect (RideB63) 30.0 y sp act, mass spect (BrowF55) others (FlyK65, FleD62a, WileDM55a, GlazM61, WileDR53, GleL51j)	☢ β^- (MelhM41) Δ −86.9 (MTW) σ_c 0.11 (GoldmDT64)	A chem, genet (MelhM41) chem, mass spect (HaydR46a, IngM49) daughter Xe^{137} (TurA51, GleL51k) parent Ba^{137m} (TownJ48)	β^- 1.176 max (7%), 0.514 max e^- 0.624, 0.656 γ Ba X-rays, 0.662 (85%) daughter radiations from Ba^{137m} included in above listing	fission (HaydR48, IngM49, GleL51j, GrumW48, FinB51c)
Cs^{138}	32.2 m (BarthR56) 32.1 m (BunkM56) others (GlasG40, WilleR60, EvaHB51, AteA39, HahO39a, GleL51k, OckD62, LangeL53a)	☢ β^- (HahO39c) Δ −83.7 (NDS, MTW)	A chem (HahO39c, HeyF39) chem, mass spect (ThuS49) descendant I^{138} (SugaN49) daughter Xe^{138} (HahO39c, HahO40, GlasG40, SeeW43a)	β^- 3.40 max γ 0.463 (23%), 0.55 (8%), 1.01 (25%), 1.426 (73%), 2.21 (18%), 2.63 (9%)	fission (HahO39c, HahO40a, HeyF39, HahO40, BunkM56) Ba^{138}(n, p) (WilleR60, SeeW43a)
Cs^{139}	9.5 m (SugaN50, ZheE63) others (AteA39, HeyF39, OckD62, HahO40)	☢ β^- (HahO39c) Δ −81.1 (MTW)	A chem, genet (HahO39c, HeyF39) daughter Xe^{139} (HahO39c, HeyF39, HahO40a, HahO40) parent Ba^{139} (HahO39c, HeyF39, HahO40a, HahO40, SugaN50)	γ 0.50, 0.63, 0.80, 1.28 (strong), 1.65 (complex), 1.90, 2.08 daughter radiations from Ba^{139}	fission (HahO39c, HeyF39, HahO40a, AteA39, SugaN50, HahO40a, HahO40, AksV62, ZheE63, OckD62)
Cs^{140}	66 s (SugaN50) 63 s (ZheE63)	☢ β^- (HahO40) Δ −77 (MTW)	A chem (HahO40) chem, genet (SugaN50) parent Ba^{140} (SugaN50)	γ 0.59, 0.88, 1.14, 1.62, 1.85, 2.06, 2.32, 2.72, 3.15	fission (HahO40, SugaN50, ZheE63)
Cs^{141}	24 s (FritK62a) 25 s (WahA62)	☢ [β^-] (BradE51)	A chem, genet (WahA62, FritK62a) parent Ba^{141} (WahA62, HahO42a) ancestor Ce^{141} (FritK62a)		fission (BradE51, DilC51a, OveR51, WahA62, FritK62a)
Cs^{142}	2.3 s (FritK62a) others (WahA62, HahO42a)	☢ [β^-] (FritK62a)	B chem, genet (FritK62a) ancestor La^{142} (FritK62a)		fission (FritK62a)
Cs^{143}	2.0 s (FritK62a)	☢ [β^-] (BradE51)	B genet (BradE51) chem, genet (FritK62a) ancestor La^{143} (FritK62a)		fission (BradE51, DilC51a)
Cs^{144}	short (DilC51, DilC51a)	☢ [β^-] (DilC51)	F genet (DilC51) [descendant Xe^{144}, ancestor Ce^{144}] (DilC51)		descendant Xe^{144} from fission (DilC51, DilC51a)
$_{56}$Ba^{123}	2.0 m (PreiI62)	☢ [β^+, EC] (PreiI62)	B chem, cross bomb, genet (PreiI62) parent Cs^{123} (PreiI62)		O^{16} on In, Sn (PreiI62) N^{14} on In (PreiI62) C^{12} on Sn (PreiI62)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12} \equiv 0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{56}Ba^{125}$	6.5 m (PreiI62)	☢ [EC, β^+] (PreiI62)	B chem, cross bomb, genet (PreiI62) parent Cs^{125} (PreiI62)		$In^{115}(N^{14}, 4n)$ C^{12} on Sn, O^{16} on In (PreiI62)
Ba^{126}	97 m (KalkM54) 103 m (PreiI62)	☢ EC (KalkM54)	A chem, genet (KalkM54) chem, cross bomb (PreiI62) parent Cs^{126} (KalkM54) daughter La^{126} (PreiI63, ShelR61)	γ 0.23 († 100), 0.70 († 33), 0.9 (weak) daughter radiations from Cs^{126}	$In^{115}(N^{14}, 3n)$ (KalkM54, PreiI62) C^{12}, O^{16} on Sn (PreiI62)
Ba^{127}	10.0 m genet (PreiI62) 12 m (KalkM54, LindnM52)	☢ β^+ (LindnM52), [EC] Δ -83 (MTW)	A chem, genet (LindnM52) chem, genet, cross bomb (PreiI62) parent Cs^{127} (LindnM52, PreiI62) daughter La^{127} (PreiI63)		O^{16}, N^{14} on In; C^{12}, O^{16} on Sn (PreiI62) $Cs^{133}(d, 8n)$ (LindnM52)
Ba^{128}	2.43 d (YafL63) 2.4 d (PreiI63, FinR50, ThomC50)	☢ EC (FinR53, LindnM52) Δ -85 (MTW)	B chem (FinR50, ThomC50) parent Cs^{128} (FinR51, LindnM52, HollaJ55) daughter La^{128} (YafL63, PreiI63)	γ Cs X-rays, 0.134, 0.278 e^- 0.128, 0.242 (above radiations with Ba^{128} or Cs^{128}) daughter radiations from Cs^{128}	$Cs^{133}(p, 6n)$ (FinR50, ThomC50, LindnM52) $Cs^{133}(d, 7n)$ (LindnM52)
Ba^{129}, Ba^{129m}?	2.61 h (β^+) (ArbE61) 2.0 to 2.4 h (conv, e^-) (ArbE61) 2.20 h (YafL63) 2.45 h (HenkW59)	☢ EC 94%, β^+ 6% (ArbE61) Δ -85 (MTW)	A chem, genet (ThomC50, FinR50) parent Cs^{129} (ThomC50, FinR50) probable isomerism shown by different half-lives of electron lines (ArbE61) daughter La^{129} (PreiI63, LavA63, YafL63)	β^+ 1.42 max e^- 0.017, 0.048, 0.093, 0.142, 0.171 others to 1.5 γ Cs X-rays, 0.129 († 26), 0.182 († 100), 0.21 († 65, complex), 0.511 ($\gamma^\pm$), 1.45 († 42) daughter radiations from Cs^{129}	$Cs^{133}(p, 5n)$ (ThomC50, FinR50, ArbE61)
Ba^{130}		% 0.101 (NierA38b) 0.13 (AkiP56) Δ -87.33(MTW) σ_c 8.8 (GoldmDT64)			
Ba^{131}	12.0 d (KatcS47a, WriH57, LyoW63, SmiKM63) 11.5 d (BegW56) 11.8 d (CorkJ53c) 11.7 d (YuF47)	☢ EC (KatcS47a) no β^+ (YuF47, FinB47) Δ -86.89 (MTW)	A chem, n-capt, excit (KatcS47a) parent Cs^{131} (KatcS47a, YuF47, YafL49, CanR51b) daughter La^{131} (YafL63) daughter Ba^{131m} (TilR63)	γ Xe X-rays, 0.124 (28%, complex), 0.216 (19%), 0.25 (5%, complex), 0.373 (13%), 0.496 (48%, complex), 0.60 (3%, doublet), 0.924 (0.8%), 1.048 (1.3%) e^- 0.019, 0.042, 0.049, 0.088, 0.097, 0.118, 0.180, 0.460 daughter radiations from Cs^{131}	$Ba^{130}(n, \gamma)$ (KatcS47a, YuF47, YafL49, DalE50, ZimE50, CanR51b) $Cs^{133}(p, 3n)$ (HiroT64)
Ba^{131m}	14.6 m (HoreD63a) 14.5 m (TilR63)	☢ IT, no EC, lim 0.1% (TilR63) Δ -86.71 (LHP, MTW)	A chem, excit, cross bomb, genet (TilR63) parent Ba^{131} (TilR63) not daughter La^{131}, lim 1% (HoreD63a)	γ Ba X-rays, 0.107 (40%) e^- [0.041, 0.071, 0.101]	$Cs^{133}(p, 3n)$ (TilR63)
Ba^{132}		% 0.097 (NierA38b) 0.19 (AkiP56) Δ -88.4 (MTW) σ_c 7 (to Ba^{133}) <0.2 (to Ba^{133m}) (GoldmDT64)			
Ba^{133}	7.2 y (KatcS56a) 10.7 y (WynE61)	☢ EC (KatcS47a) no β^+, lim 0.1% (LangeM56) Δ -87.67 (MTW)	A chem, n-capt, excit (KatcS47a) chem, genet (YuF48) daughter Ba^{133m} (YuF48)	γ Cs X-rays, 0.080 (36%, complex), 0.276 (7%), 0.302 (14%), 0.356 (69%), 0.382 (8%) e^- 0.045, 0.075, 0.266, 0.319	$Ba^{133}(n, \gamma)$ (KatcS47a, CrasB57) $Cs^{133}(p, n)$ (GupR58)
Ba^{133m}	38.9 h (WilleR60, YuF48) others (MocD48)	☢ IT (CorkJ41) Δ -87.39 (LHP, MTW)	A chem, excit (CorkJ41, DubL40a) parent Ba^{133} (YuF48)	γ Ba X-rays, 0.276 (17%) e^- 0.006, 0.011, 0.238, 0.270	$Cs^{133}(p, n)$ (DubL40a) $Cs^{133}(d, 2n)$ (CorkJ41, HillR51b, HillR51d) $Ba^{132}(n, \gamma)$ (YuF48)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (△≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$\underline{{}_{56}Ba^{134}}$		% 2.42 (NierA38b) 2.60 (AkiP56) Δ −88.85 (MTW) σ_c <4 (to Ba^{135}) 0.16 (to Ba^{135m}) (GoldmDT64)			
$\underline{Ba^{135}}$		% 6.59 (NierA38b) 6.7 (AkiP56) Δ −88.0 (MTW) σ_c 5 (GoldmDT64)			
Ba^{135m}	28.7 h (WilleR60, YuF48)	☢ IT (WeimK43a, YuF48) Δ −87.7 (MTW, LHP)	A chem (KalbD40) chem, n-capt, sep isotopes (HillR51b) not daughter La^{135} (MoriS65)	γ Ba X-rays, 0.268 (16%) e^- 0.231, 0.262	Ba^{134}(n, γ) (HillR51b, KalbD40)
Ba^{135}	0.32 s (FetP62a) others (CamE59)		G sep isotopes (FetP62a) assigned to Ba^{136m} (RudF65)		neutrons on Ba^{135} (FetP62a, CamE59)
$\underline{Ba^{136}}$		% 7.81 (NierA38b) 8.1 (AkiP56) Δ −89.1 (MTW) σ_c <1 (to Ba^{137}) 0.010 (to Ba^{137m}) (GoldmDT64)			
Ba^{136m}	0.32 s (FetP62a) 0.37 s (RudF65) others (CamE59)	☢ IT (RudF65) Δ −87.1 (LHP, MTW)	B chem, genet, genet energy levels (RudF65)	γ Ba X-rays, 0.164 (40%), 0.818 (100%), 1.05 (100%) e^- [0.126, 0.158]	daughter Cs^{136} (RudF65)
$\underline{Ba^{137}}$		% 11.32 (NierA38b) 11.9 (AkiP56) Δ −88.0 (MTW) σ_c 4 (GoldmDT64)			
Ba^{137m}	2.554 m (MerJ65) 2.60 m (MitA49) 2.6 m (TownJ48, WilleR60)	☢ IT (TownJ48) Δ −87.4 (LHP, MTW)	A n-capt (AmaE35) chem, genet (TownJ48) daughter Cs^{137} (TownJ48)	γ Ba X-rays, 0.662 (89%) e^- 0.624, 0.656	daughter Cs^{137} (TownJ48)
$\underline{Ba^{138}}$		% 71.66 (NierA38b) 70.4 (AkiP56) Δ −88.5 (MTW) σ_c 0.4 (GoldmDT64)			
Ba^{139}	82.9 m (ButlJP58, FritK62) 84.0 m (BaeA57) 85.0 m (DilC51c) others (WilleR60, ShepL48, HahO40, KellWH60, PoolM37a)	☢ β^- (PoolM37a) Δ −85.1 (MTW) σ_c 4 (GoldmDT64)	A chem, n-capt (AmaE35) chem, excit (PoolM38a) daughter Cs^{139} (HahO39c, HeyF39, HahO40a, HahO40, SugaN50) descendant Xe^{139} (HahO39c, HeyF39, DilC51a) descendant I^{139} (SugaN49)	β^- 2.3 max e^- 0.126, 0.159 γ La X-rays, 0.166 (23%), 1.43 (0.4%)	Ba^{138}(n, γ) (AmaE35, PoolM37, SerL47b, YafL49a) fission (HeyF39, HahO39c, DilC51a, KatcS48, FinB51c)
Ba^{140}	12.80 d (EngeD51c) 12.8 d (VasiI58)	☢ β^- (HahO39c) Δ −83.31 (MTW) σ_c <20 (GoldmDT64)	A chem, genet (HahO39, HahO39c) parent La^{140} (HahO39, HahO39c, HahO40, GlasG40, HahO42a, GrumW46, FinB51b) daughter Cs^{140} (SugaN50) descendant Xe^{140} (HanO40, BradE51, DilC51a, DilC51, OveR51)	β^- 1.02 max e^- 0.024, 0.029 γ La X-rays, 0.030 (11%), 0.163 (6%), 0.305 (6%), 0.438 (5%), 0.537 (34%) daughter radiations from La^{140}	fission (HahO39, HeyF39, HahO40, GlasG40, GrumW46, SugaN50, DilC51a, DilC51, BradE51, OveR51, WilkR51, EngeD51c, EngeD51d, KatcS48, FinB51c)
Ba^{141}	18 m (SchumR59, FritK62, HahO42a, GoldsA51)	☢ β^- (HahO42a) Δ −80.1 (MTW)	A chem, genet (HahO42a) daughter Cs^{141} (HahO42a, WahA62) parent La^{141} (HahO62a) descendant Xe^{141} (BradE51, OveR51, DilC51a) others (HahO39a, HahO39, GoldsA51a, LangeA40)	β^- 3.0 max γ La X-rays, 0.118 (↑ 10), 0.193 (↑ 100), 0.28 (↑ 50), 0.31 ? (↑ 60), 0.35 (↑ 20), 0.46 (↑ 30, complex), 0.64 (↑ 20, complex?), 0.73 (↑ 7), 0.86 (↑ 6), 0.93 (↑ 3), 1.19 (↑ 8), 1.29 (↑ 3), 1.42 (↑ 4), 1.65 (↑ 3) daughter radiations from La^{141}	fission (HahO42a, GoldsA51, GoldsA51a, BradE51, OveR51, DilC51a, SchumR59, FritK62, NagaK60)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}≡0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{56}$Ba^{142}	11 m (SchumR59, FritK62a) others (HahO42a)	☢ β^- (HahO42a) Δ −77.9 (MTW)	B chem, genet (HahO42a) parent La^{142} (HahO42a) others (HahO39a, HahO39, LangeA40)	β^- 1.7 max γ La X-rays, 0.080 (↑ 30), 0.26 (↑ 100), 0.89 (↑ 40), 0.97 (↑ 15), 1.08 (↑ 10), 1.20 (↑ 35) daughter radiations from La^{142}	fission (SchumR59, FritK62, HahO42a)
Ba^{143}	12 s (WahA62)	☢ β^- (HahO42a)	B chem, genet (HahO42a) chem (WahA62) parent La^{143} (HahO42a)		fission (HahO42a, WahA62, FritK62a)
Ba^{144}	short (DilC51a, DilC51)	☢ [β^-] (DilC51a)	F genet (DilC51a) [descendant Xe^{144}, ancestor Ce^{144}] (DilC51a, DilC51)		descendant Xe^{144} from fission (DilC51, DilC51a)
$_{57}$La^{125}	<1 m (PreiI63)	☢	F chem, genet [ancestor Cs^{125}] (PreiI63)		O^{16} on In (PreiI63)
La^{126}	1.0 m (ShelR61, PreiI63)	☢ [β^+, EC] (ShelR61)	B chem, cross bomb, genet (ShelR61) chem (PreiI63) parent Ba^{126} (PreiI63, ShelR61)	γ Ba X-rays, 0.256, 0.511 ($\gamma^{\pm}$)	In^{115}(O^{16}, 5n) (ShelR61, PreiI63) Sb^{121}(C^{12}, 7n) (ShelR61)
La^{127}	3.5 m genet (YafL63) 3.8 m genet (PreiI63)	☢ [β^+, EC] (PreiI63, YafL63)	B chem, genet (PreiI63, YafL63) parent Ba^{127} (PreiI63) ancestor Cs^{127} (YafL63)		C^{12} on Sb (YafL63) O^{16} on In (PreiI63)
La^{128}	4.2 m (PreiI63) 4.6 m (YafL63) 6 m (ShelR61)	☢ [β^+, EC] (ShelR61)	B chem, cross bomb (ShelR61) chem, genet (YafL63, PreiI63) parent Ba^{128} (PreiI63, YafL63) ancestor Cs^{128} (YafL63)	γ Ba X-rays, 0.279, 0.511 ($\gamma^{\pm}$)	Sb^{121}(C^{12}, 5n) (ShelR61, YafL63) Sb^{123}(C^{12}, 7n) (ShelR61, YafL63) In^{115}(O^{16}, 3n) (ShelR61, PreiI63)
La^{129}	10.0 m (YafL63) 7.2 m genet (PreiI63) ≈24 m (LavA63)	☢ [β^+, EC] (PreiI63, LavA63, YafL63) Δ −81 (MTW)	A chem, genet (PreiI63, LavA63) chem, sep isotopes, cross bomb, genet (YafL63) parent Ba^{129} with $t_{1/2}$ 2.20 h (YafL63), 2.1 to 2.4 h (LavA63) daughter Ce^{129} (LavA63)		C^{12} on Sb (YafL63) O^{16} on In (PreiI63)
La^{130}	8.7 m (YafL63) 9 m (ShelR61)	☢ β^+, EC (ShelR61, YafL63) Δ −82 (MTW)	A chem, cross bomb, genet energy levels (ShelR61) chem, sep isotopes (YafL63)	γ Ba X-rays, 0.356, 0.45, 0.511 ($\gamma^{\pm}$), 0.55, 0.72, 0.81, 0.91, 1.01, 1.19, 1.45, 1.55	Ba^{130}(p, n) (YafL63) Sb^{121}(C^{12}, 3n) (ShelR61) Sb^{123}(C^{12}, 5n) (ShelR61)
La^{131}	56 m genet (YafL63) 61 m (CreC60) 58 m (GranM51)	☢ EC 72%, β^+ 28% (CreC60) Δ −83.9 (MTW)	A chem, mass spect (GranM51) chem, genet (YafL63) parent Ba^{131} (YafL63) not parent Ba^{131m}, lim 1% (HoreD63a)	β^+ 1.94 max e^- 0.078, others γ Ba X-rays, 0.115 (23%), 0.169 (5%), 0.214 (8%), 0.285 (17%), 0.364 (20%), 0.417 (20%), 0.455 (8%), 0.511 (56%, $\gamma^{\pm}$), 0.597 (7%), 0.878 (4%)	Ba^{130}(d, n) (CreC60) Sb^{123}(C^{12}, 4n) (YafL63, HoreD63a)
La^{132}	4.5 h (GranM51) 4.8 h (WareW60) 4.2 h (GrigE60)	☢ β^+ (GranM51), [EC] Δ −83.1 (LHP, MTW)	A chem, mass spect (GranM51) daughter Ce^{132} (WareW60)	β^+ 3.8 max γ Ba X-rays, 0.47, 0.511 ($\gamma^{\pm}$), 0.56, 0.66, 0.90 (doublet), 1.03, 1.22, 1.58, 1.92	protons on Ba (GranM51)
La^{133}	4.0 h (NauR50)	☢ EC, β^+ (weak) (NauR50) Δ −85.5 (MTW)	A chem, mass spect (NauR50) daughter Ce^{133} (StovB51)	γ Ba X-rays, 0.511 ($\gamma^{\pm}$), 0.8 β^+ 1.2 max e^- 0.26	Cs^{133}(α, 4n) (NauR50)
La^{134}	6.8 m (GirR59a) 6.5 m (StovB51)	☢ β^+ 62%, EC 38% (GirR59a) β^+ ≈44%, EC ≈56% (StovB51) Δ −85.1 (MTW)	B chem, genet (StovB51) daughter Ce^{134} (StovB51)	β^+ 2.7 max γ Ba X-rays, 0.511 (124%, $\gamma^{\pm}$), 0.605 (6%)	daughter Ce^{134} (StovB51) Cs^{133}(α, 3n) (GirR59a)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}≡0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{57}$La^{135}	19.4 h (MoriS65) 19.8 h (MitA58) 19.5 h (ChubJ48) others (NauR50, WeimK43)	☢ EC (MounK42, ChubJ48) no β^+, lim 0.002% (MoriS65) others (GrenH65, MitA58) Δ −87.0 (MoriS65, MTW)	A chem (MounK42) chem, excit (ChubJ48) chem, mass spect (NauR50) daughter Ce^{135} (ChubJ48) not parent Ba^{135m} (MoriS65)	γ Ba X-rays, 0.481 (1.9%), 0.588 (0.13%), 0.87 (0.24%, complex) e$^-$ 0.181, 0.444, 0.475	Cs^{133}(α, 2n) (ChubJ48, NauR50, MitA58) Ba^{134}(d, n) (MounK42, WeimK43) Ba^{138}(p, 4n) (MoriS65) Ba^{135}(p, n) (WeimK43)
La^{136}	9.5 m (NauR50) 9.0 m (RobeB50) 10.0 m (GirR59) others (MauW47)	☢ EC ≈67%, β^+ ≈33% (NauR50) Δ −86.3 (MTW)	A chem (MauW47) chem, excit, sep isotopes (RobeB50)	β^+ 1.9 max γ Ba X-rays, 0.511 (66%, $\gamma^{\pm}$), 0.818 (2.5%)	Cs^{133}(α, n) (RobeB50, NauR50, GirR59) Ba^{135}(d, n), Ba^{136}(d, 2n) (RobeB50)
La^{137}	6 x 10^4 y sp act (BrosA56) others (ChubJ48, IngM48c, BrosA55)	☢ EC (BrosA56) Δ −88 (MTW)	A mass spect (IngM48c) chem (BrosA56)	γ Ba X-rays	Ce^{136}(n, γ)Ce^{137}(β^-) (IngM48c, BrosA56, BrosA55, ChubJ48)
La^{138}	1.12 x 10^{11} y sp act (GloR57) 1.1 x 10^{11} y sp act (TurW56) others (PriR51, MulhG52a)	☢ EC ≈70%, β^- ≈30% (GloR57) EC 53%, β^- 47% (TurW56) EC ≈94%, β^- ≈6% (MulhG52a) % 0.089 (IngM47e, WhiF56) Δ −86.7 (MTW)	A chem, mass spect (IngM47e)	β^- 0.21 max γ Ba X-rays, 0.81 (30%), 1.426 (70%)	
La^{139}		% 99.911 (WhiF56, IngM47e) Δ −87.43 (MTW) σ_c 8.9 (GoldmDT64)			
La^{140}	40.22 h (KirH54) 40.27 h (PepD57) 40.3 h (YafL54a) 40.0 h (BallN51b, BisG50, WeimK43)	☢ β^- (PoolM38a) Δ −84.36 (MTW)	A n-capt (MarsJK35) chem, excit, n-capt (PoolM38a) chem, mass spect (HaydR48) daughter Ba^{140} (HahO39, HahO39c, HahO40, GlasG40, HahO42a, GrumW46, FinB51b)	β^- 2.175 max (6%), 1.69 max (15%), 1.36 max γ 0.329 (20%), 0.487 (40%), 0.815 (19%), 0.923 (10%), 1.596 (96%), 2.53 (3%)	La^{139} (n, γ) (MarsJK35, PoolM38a, GotH42, WeimK43, SerL47b) fission, daughter Ba^{140} (HahO39, HahO39c, HahO40, GlasG40, HahO42a, GrumW46, FinB51b, GrumW48, GrumW47, FinB51c)
La^{141}	3.87 h (AlsJ60) 3.90 h (FritK62) others (SchumR59, RydH58, KatcS51i, HahO42a)	☢ β^- (HahO42a) Δ −83.06 (MTW)	A chem (HahO42a) chem, genet (BurgW51, DufR51a) daughter Ba^{141} (HahO42a) parent Ce^{141} (BurgW51, DufR51a) descendant Xe^{141} (BradE51) others (KatcS49, CuriI39, BallN51h)	β^- 2.43 max γ 1.37 (2%) daughter radiations from Ce^{141}	fission (HahO42a, KatcS51i, Schum R59, AlsJ60, FritK62)
La^{142}	92.5 m (FritK62) 81 m (RydH58) 77 m (KatcS51i, BosA53, WilleR60) others (HahO42a)	☢ β^- (KatcS51i) Δ −80.1 (MTW)	A chem (HahO42a, PresW64) sep isotopes, excit (WolfsK60) genet energy levels (PresW64, HansO63) daughter Ba^{142} (HahO42a) descendant Cs^{142} (FritK62a) descendant Xe^{142} (WolfsK60)	β^- 4.51 max γ 0.65 (48%), 0.90 (9%), 1.01 (5%), 1.06 (4%), 1.55 (5%, complex), 1.74 (5%), 1.91 (9%), 2.06 (6%), 2.41 (15%), 2.55 (11%), 2.99 (5%), 3.31 (1.9%), 3.65 (2.3%)	fission (PresW64, HahO42a, KatcS51i, HahO43a, GesH51, RydH58, BosA53, FritK62, SchumR59) Ce^{142}(n, p) (WilleR60, WolfsK60)
La^{143}	14.0 m (FritK61a) others (HahO43a, GesH51)	☢ β^- (GesH51) Δ −78.4 (MTW)	A chem, genet (GesH51) parent Ce^{143} (GesH51) daughter Ba^{143} (HahO42a) descendant Cs^{143} (FritK62a)	β^- 3.3 max γ 0.62 (↑ 100), 0.80 (↑ 44), 1.07 (↑ 26), 1.17 (↑ 57), 1.58 (↑ 28), 1.98 (↑ 35), 2.56 (↑ 27)	fission (HahO42a, HahO43a, GesH51)
La^{144}	short (DilC51)	☢ [β^-] (DilC51) Δ −75 (MTW)	F genet (DilC51) [descendant Xe^{144}, ancestor Ce^{144}] (DilC51)		descendant Xe^{144} from fission (DilC51)
$_{58}$Ce^{129}	≈13 m (LavA63)	☢ [β^+, EC] (LavA63)	E chem, genet (LavA63) parent La^{129} (LavA63)	γ La X-rays, 0.080, 0.32, 0.75 daughter radiations from La^{129}, Ba^{129}	protons on Pr (LavA63)
Ce^{130}	30 m (AlboG65, WareW60)	☢ [EC, β^+] (AlboG65, GersG65)	B chem, mass spect (AlboG65)	γ [La X-rays), 0.13 daughter radiations from La^{130}	La^{139}(p, 10n) (GersG65)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV (C' 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{58}$Ce^{132}	4.2 h genet (WareW60)	☢ [EC] (WareW60) Δ -82 (MTW)	B chem, genet (WareW60) parent La^{132} (WareW60)	γ [La X-rays], 0.18 daughter radiations from La^{132}	protons on Ce (WareW60)
Ce^{133}	6.3 h (StovB51)	☢ EC, β^+ (StovB51) Δ -83 (MTW)	B chem, genet (StovB51) parent La^{133} (StovB51)	β^+ 1.3 max γ La X-rays, 0.511 ($\gamma^\pm$), 1.8 daughter radiations from La^{133}	La^{139}(p, 7n) (StovB51)
Ce^{134}	72.0 h (StovB51) 72 h (LavA60)	☢ EC (StovB51) Δ -84.9 (MTW)	B chem, excit (StovB51) parent La^{134} (StovB51) daughter Pr^{134} (LavA60, LavA63)	γ La X-rays, 0.44? daughter radiations from La^{134}	La^{139}(p, 6n) (StovB51)
Ce^{135}	17.0 h (DzhB63a) 17.6 h (TakaKa64) others (StovB51, ChubJ48)	☢ EC, β^+ <1% (StovB51) Δ -85 (MTW)	A chem, genet (ChubJ48) parent La^{135} (ChubJ48) daughter Pr^{135} (HandT54c)	γ La X-rays, 0.205 (↑ 17), 0.265 (↑ 100), 0.300 (↑ 56), 0.39 (↑ 10, complex), 0.52 (↑ 46, complex), 0.59 (↑ 98, complex), 0.777 (↑ 22), 0.821 (↑ 22), 0.865 (↑ 14), 0.901 (↑ 10) e^- 0.048, 0.078, 0.166, 0.225, 0.25 β^+ 0.81 max daughter radiations from La^{135}	La^{139}(p, 5n) (StovB51, TakaKa64) La^{139}(d, 6n) (ChubJ48)
Ce^{136}	$t_{1/2}$ (EC$_K$) >2.9 x 10^{11} y sp act (HohK65)	% 0.193 (IngM47e) Δ -86.6 (MTW) σ_c 6.0 (to Ce^{137}) 0.6 (to Ce^{137m}) (GoldmDT64)			
Ce^{137}	9.0 h (DanbG58) 8.7 h (BrosA55)	☢ EC 99+%, β^+ ≤0.009% (StonN65a, LHP) Δ -86 (MTW)	A chem, n-capt (BrosA55) chem, genet (DanbG58) daughter Ce^{137m} (DanbG58) daughter Pr^{137} (DanbG58, DahC58)	γ La X-rays, 0.446 (2.3%, complex), 0.481 (0.06%, complex), 0.698 (0.04%), 0.92 (0.10%, complex) e^- [0.004, 0.009], 0.408	daughter Pr^{137} (DanbG58, DahC58) La^{139}(p, 3n) (DanbG58) Ce^{136}(n, γ) (FranR64) alphas on Ba (BrosA55)
Ce^{137m}	34.4 h (DanbG58) others (BrosA55, DanbG56, ChubJ48)	☢ IT 99.4%, EC 0.6% (StonN65a, LHP) Δ -87 (LHP, MTW)	A chem, excit (ChubJ48) n-capt, sep isotopes (HillR51a) parent Ce^{137} (DanbG58) not daughter Pr^{137} (DanbG58)	γ Ce X-rays, 0.168 (0.4%), 0.255 (11%), 0.762 (0.16%), 0.825 (0.5%, complex) e^- 0.214, 0.248 daughter radiations from Ce^{137}	La^{139}(p, 3n) (DanbG58) Ce^{136}(n, γ) (HillR51a, KellH51, FranR64) alphas on Ba (BrosA55)
Ce^{138}		% 0.250 (IngM47e) Δ -87.7 (MTW) σ_c 1.0 (to Ce^{139}) 0.04 (to Ce^{139m}) (GoldmDT64)			
Ce^{139}	140 d (PoolM48, PoolM43) others (WilleR60)	☢ EC (EC(L)/EC(K) 0.37) (KetB56) EC(L)/EC(K) 0.21 (PruC54) Δ -87.16 (MTW)	A chem (PoolM43) chem, excit, cross bomb (PoolM48) n-capt, sep isotopes (HillR51a) daughter Pr^{139} (StovB51, HandT54c, DanbG58) descendant Nd^{139m} (StovB51)	γ La X-rays, 0.165 (80%) e^- 0.126, 0.159	Ce^{138}(n, γ) (HillR51a, KellH51, MosA50) La^{139}(d, 2n) (PoolM43, PoolM48)
Ce^{139m}	54 s (JameR60) 60 s (KotK60) 55 s (KetB56)	☢ IT (KetB56) Δ -86.41 (LHP, MTW)	B n-capt (KetB56) not daughter Pr^{139} (DanbG58)	γ Ce X-rays, 0.746 (93%) e^- 0.706, 0.740	Ce^{138}(n, γ) (KetB56) La^{139}(p, n) (JameR60)
Ce^{140}		% 88.48 (IngM47e) Δ -88.13 (MTW) σ_c 0.6 (GoldmDT64)			
Ce^{141}	32.5 d (FreeM50a) 33.1 d (WalkD49a) others (PoolM48, WilleR60)	☢ β^- (HahO40c) Δ -85.49 (MTW) σ_c 30 (GoldmDT64)	A chem (HahO40c) chem, excit, n-capt, cross bomb (PoolM43, BallN51d) chem, mass spect (HaydR48) daughter La^{141} (BurgW51, DufR51a) descendant Cs^{141} (FritK62a) descendant Xe^{141} (OveR51, DilC51, DilC51a)	β^- 0.581 max e^- 0.104, 0.139 γ Pr X-rays, 0.145 (48%)	Ce^{140}(n, γ) (PoolM43, BallN51d, IngM48c) daughter La^{141} (BurgW51, DufR51a) Pr^{141}(n, p) (PoolM43)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{58}$Ce^{142}	t$_{1/2}$ (α) >5 x 10^{16} y sp act (MacfR61a) others (SenF59, RieW57)	% 11.07 (IngM47e) ☢ no α (MacfR61a, SenF59) α (RieW57) Δ −84.63 (MTW) σ_c 1 (GoldmDT64)			
Ce^{143}	33 h (VasiI58, MartiDW56, BallN51d, StovB50, BotW46a) 34 h (KondE51c, WilleR60) others (BunyD49, PoolM43)	☢ β^- (SugaN46) Δ −81.67 (MTW) σ_c 6 (GoldmDT64)	A chem (SugaN46, PoolM43) chem, cross bomb (PoolM48) chem, genet (BallN51d) mass spect (IngM48c) daughter La^{143} (GesH51) parent Pr^{143} (PoolM43, BotW46a, BallN51d) descendant Xe^{143} (BradE51, DilC51a)	β^- 1.39 max e^- 0.015, 0.051, 0.252 γ Pr X-rays, 0.057 (11%), 0.293 (46%), 0.493 (2.4%), 0.668 (7%), 0.725 (8%), 0.88 (1.4%), 1.10 (0.6%) daughter radiations from Pr^{143}	Ce^{142}(n, γ) (KellH51, PoolM43, BotW46a, PoolM48, BallN51d)
Ce^{144}	284 d (FlyK65a) 285 d (SchumR56, MerW57) 277 d (EasH60) others (BurgW51a, JoliF44)	☢ β^- (HahO40c) Δ −80.49 (MTW) σ_c 1.0 (GoldmDT64)	A chem (HahO40c) chem, mass spect (HaydR48) parent Pr^{144} (HahO43a, NewA51a) descendant Xe^{144} (DilC51)	β^- 0.31 max e^- 0.038, 0.092 γ Pr X-rays, 0.080 (2%), 0.134 (11%) daughter radiations from Pr^{144}	fission (HahO40c, BornH43a, DilC51a, NewA51a, BurgW51a, GrumW48, FinB51c)
Ce^{145}	3.0 m (MarkS54) 3.1 m (WilleR60)	☢ β^- (MarkS54) Δ −77 (MTW)	B chem, excit, genet (MarkS54) parent Pr^{145} (MarkS54)	β^- 2.0 max γ γ rays reported	fission (MarkS54) Nd^{148}(n, α) (WilleR60)
Ce^{146}	14 m (CareA53) 15 m (SchumR45) others (GotH46)	☢ β^- (GotH43) Δ −75.8 (MTW)	B chem, genet (GotH43) parent Pr^{146} (GotH43, HahO43a, GotH46, CareA53)	β^- 0.7 max γ Pr X-rays, 0.110 (↑ 20), 0.142 (↑ 42), 0.22 (↑ 50), 0.27 (↑ 12), 0.32 (↑ 100) daughter radiations from Pr^{146}	fission (GotH43, HahO43a, SchumR45, GotH46, BernsW54)
Ce^{147}	65 s genet (HoffD64)	☢ β^- (HoffD64)	B chem, genet (HoffD64) parent Pr^{147} (HoffD64)		fission (HoffD64)
Ce^{148}	≈43 s genet (HoffD64)	☢ β^- (HoffD64)	B chem, genet (HoffD64) parent Pr^{148} (HoffD64)		fission (HoffD64)
$_{59}$Pr^{134}	17 m (ClarJ65) 40 m genet (LavA63) others (LavA60)	☢ β^+ (ClarJ65), [EC]	B chem, genet (LavA60, LavA63) chem, excit, genet energy levels (ClarJ65) parent Ce^{134} (LavA60, LavA63)	γ Ce X-rays, 0.22, 0.30, 0.409, 0.511 ($\gamma^{\pm}$), 0.639, 0.96 daughter radiations from Ce^{134}, La^{134}	I^{127}(C^{12}, 5n) (ClarJ65) protons on Pr (LavA63)
Pr^{135}	22 m (HandT54c)	☢ β^+, EC (HandT54c)	B chem, excit, genet (HandT54c) parent Ce^{135} (HandT54c)	β^+ 2.5 max γ Ce X-rays, 0.080, 0.22, 0.30, 0.511 ($\gamma^{\pm}$) daughter radiations from Ce^{135}	Ce^{136}(p, 2n) (HandT54c)
Pr^{136}	1.2 h (HandT54c) 1.0 h (DanbG58)	☢ EC ≈67%, β^+ ≈33% (DanbG58)	A chem, excit (HandT54c) chem, mass spect (DanbG58)	β^+ 2.0 max γ Ce X-rays, 0.17?, 0.511 (66%, $\gamma^{\pm}$)	Ce^{136}(p, n) (HandT54c) protons on Ce, Pr (DanbG58)
Pr^{137}	1.5 h (DanbG58, DahC58)	☢ EC 73%, β^+ 27% (DanbG58) Δ −84 (MTW)	B chem, mass spect (DanbG58, DahC58) parent Ce^{137}, not parent Ce^{137m} (DanbG58) daughter Nd^{137} (GromK65)	β^+ 1.7 max γ Ce X-rays, 0.511 (54%, $\gamma^{\pm}$), no other γ's (lim 6%) daughter radiations from Ce^{137}	protons on Ce (DanbG58, DahC58)
Pr^{138}	2.10 h (DanbG58) 2.2 h (FujM64) 2.0 h (StovB51, HandT54c)	☢ EC 77%, β^+ 23% (FujM64) EC 84%, β^+ 16% (DanbG58) others (StovB51) Δ −82.9 (FujM64, MTW)	A chem, excit (StovB51) chem, mass spect (DanbG58)	β^+ 1.65 max e^- 0.258, 0.292 γ Ce X-rays, 0.298 (77%), 0.40 (9%), 0.511 (46%, $\gamma^{\pm}$), 0.79 (100%), 1.04 (100%)	Ce^{140}(p, 3n) (StovB51, DanbG58, FujM64) Ce^{138}(p, n) (HandT54c)
Pr^{138}	short (GromK64)	☢ (GromK64)	F genet (GromK64) [daughter ≈5 h Nd^{138}] (GromK64)		daughter ≈5 h Nd^{138} (GromK64)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12} = 0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{59}Pr^{139}$	4.5 h (DanbG58, StovB51, HandT54c) 4.9 h (BiryE63a)	☢ EC 89%, β^+ 11% (BiryE63a) EC 93%, β^+ 7% (DanbG58) EC ≈94%, β^+ ≈6% (StovB51) others (BoreO61) Δ −85.0 (BiryE63a, MTW)	A chem, genet (StovB51) chem, mass spect, genet (DanbG58) parent Ce^{139} (StovB51, HandT54c, DanbG58) not parent Ce^{139m} (DanbG58)	β^+ 1.09 max γ Ce X-rays, 0.511 (18%, $\gamma^{\pm}$), 1.35 (0.5%), 1.61 (0.3%)	$Pr^{141}(p, 3n)Nd^{139}(\beta^-)$ (DanbG58) $Ce^{140}(p, 2n)$ (StovB51, DanbG58)
$Pr^{139m?}$	≈6 m (KolG63)	☢	F genet (KolG63) daughter Nd^{139} or Nd^{139m}? (KolG63)		daughter Nd^{139m} (KolG63)
Pr^{140}	3.39 m (EbrT65) others (DWirJ42, HandT54c, PoolM38a, BiryE62, WilleR60, StovB51, HubeO45, PerlmM49)	☢ EC 50%, β^+ 50% (BrabV60) EC(K)/EC(L) 8 (BiryE60) others (BiryE60, BiryE62, BrowCI52) Δ −84.78 (HisK64, MTW)	A excit (AmaE35) excit (PoolM38a) daughter Nd^{140} (WilkG49c, BrowCI52)	β^+ 2.32 max e^- 1.862 (0.07%) γ Ce X-rays, 0.511 (100%, $\gamma^{\pm}$), 1.596 (0.3%)	daughter Nd^{140} (WilkG49c, BrowCI52, HisK64)
Pr^{141}	$t_{1/2}$ (α) >2 x 10^{16} y sp act (PorsW54)	% 100 (IngM48a, CollT57) Δ −86.07 (MTW) σ_c 12 (GoldmDT64)			
Pr^{142}	19.2 h (WyaE61, BotW46a) 19.3 h (DWirJ42) 19.1 h (JensE50) others (WilleR60)	☢ β^- (DWirJ42) no EC or β^+, lim 0.5% (ReynJH50b) Δ −83.85 (MTW) σ_c 20 (GoldmDT64)	A n-capt (AmaE35, MarsJK35)	β^- 2.16 max γ 1.57 (3.7%)	$Pr^{141}(n, \gamma)$ (AmaE35, MarsJK35, PoolM37, PoolM38a, DWirJ42, SerL47b)
Pr^{143}	13.59 d (PepD57) 13.76 d (WriH57) 13.6 d (HoffD63) others (FelL49, BallN51f, RoyL56, PoolM48, MartiDW56)	☢ β^- (BallN51e, JoliF44) Δ −83.11 (MTW) σ_c 89 (GoldmDT64)	A chem (BallN51e, JoliF44) mass spect (HaydR46a) daughter Ce^{143} (PoolM43, BotW46a, BallN51d) others (HahO43a, FinB51c)	β^- 0.933 max average β^- energy: 0.31 calorimetric (HovV64) γ no γ	$Ce^{142}(n, \gamma)Ce^{143}(\beta^-)$ (PoolM43, BotW46a, BallN51d) fission (HahO43a, JoliF44, BallN51e, FinB51c)
Pr^{144}	17.27 m (PepD57) 17.30 m (HoffD63) others (NewA51a, SeiJ51b, HahO43a, GrumW46)	☢ β^- (NewA51a) Δ −80.81 (MTW)	A chem, genet (NewA51a, HahO43a) daughter Ce^{144} (HahO43a, NewA51a)	β^- 2.99 max γ 0.695 (1.5%), 1.487 (0.29%), 2.186 (0.7%)	daughter Ce^{144} (HahO43a, NewA51a)
Pr^{145}	5.98 h (DroB59) 5.9 h (MarkS54, AlsJ60)	☢ β^- (MarkS54) Δ −79.66 (MTW)	B chem, excit (MarkS54) chem, sep isotopes (HoffD64) daughter Ce^{145} (MarkS54)	β^- 1.80 max γ 0.072, 0.68, 0.75, 0.92, 0.98, 1.05, 1.16	fission (MarkS54, DroB59, AlsJ60, HoffD64) $Nd^{146}(\gamma, p)$ (HoffD64)
Pr^{146}	24.0 m (HoffD64) others (SchumR45a, CareA53, GotH46)	☢ β^- (GotH43) Δ −76.8 (MTW)	B chem, genet (GotH43) daughter Ce^{146} (GotH43, HahO43a, GotH46, CareA53)	β^- 3.7 max γ 0.455 (77%), 0.74 (16%), 0.78 (15%), 0.92 (6%), 1.37 (6%), 1.51 (27%), 1.72 (4%), 2.23 (4%), 2.39 (3%), 2.73 (1.7%)	fission (GotH43, HahO43a, SchumR45, GotH46, BernsW54, HoffD64) $Nd^{146}(n, p)$ (RamayA65)
Pr^{147}	12.0 m (HoffD64) 12 m (WilleR60)	☢ β^- (HoffD64) Δ −75.5 (HoffD64, MTW)	B chem, genet (HoffD64) parent Nd^{147}, daughter Ce^{147} (HoffD64)	β^- 2.1 max γ 0.078 (17%, complex?), 0.127 (9%, complex?), 0.32 (47%, complex), 0.56 (39%), 0.61 (10%), 0.65 (24%), 1.26 (11%)	$Nd^{148}(\gamma, p)$, fission (HoffD64)
Pr^{148}	2.0 m (HoffD64)	☢ β^- (HoffD64) Δ −72.9 (HoffD64, MTW)	B chem, genet energy levels (HoffD64) daughter Ce^{148} (HoffD64)	β^- 4.2 max γ 0.30	fission (HoffD64)
Pr^{149}	2.3 m (HoffD64)	☢ β^- (HoffD64)	E excit, sep isotopes (HoffD64)	β^- 2.8 max γ 0.08, 0.155, 0.325, 0.36, 0.745	$Nd^{150}(\gamma, p)$ (HoffD64)
$_{60}Nd^{137}$	55 m (GromK65)	☢ β^+, [EC] (GromK65)	B chem, atomic level spacing, genet (GromK65) parent Pr^{137} (GromK65)	β^+ 3 max e^- 0.067 γ [Pr X-rays, 0.109, 0.511 ($\gamma^{\pm}$), 0.55 (complex)] daughter radiations from Pr^{137}, Ce^{137}	protons on Ta, Er (GromK65)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{60}$Nd^{138}	22 m (StovB51)	☢ β^+ (StovB51), [EC]	D chem, excit (StovB51)	β^+ 2.4 max γ [Pr X-rays, 0.511 ($\gamma^{\pm}$)]	Pr^{141}(p, 4n) (StovB51)
Nd^{138}	≈5 h (GromK64)	☢ (GromK64)	F chem (GromK64)		protons on Ta, Er (GromK64)
Nd^{139}	[<<5 h] (GromK63b)	☢ [EC, β^+] Δ −82 (MTW)	F [genet] (GromK63b) [daughter Nd^{139m}] (GromK63b)	β^+, γ see Nd^{139m}	[daughter Nd^{139m}] (GromK63b)
Nd^{139m}	5.5 h (StovB51) 5.2 h (BoncN61)	☢ IT (+EC+β^+?) (GromK63b) EC ≈90%, β^+ ≈10% (with Nd^{139}) (StovB51) Δ −82 (LHP, MTW)	B chem, genet (StovB51) atomic level spacing (GromK63b) ancestor Ce^{139} (StovB51)	β^+ 3.1 max e^- 0.072, 0.107, 0.189, 0.226 γ Nd X-rays, Pr X-rays, 0.114 (↑ 80), 0.327 (↑ 50), 0.511 (↑ 1400), 0.73 (↑ 210, complex), 0.82 (↑ 70, complex), 0.90 (↑ 25), 0.983 (↑ 70), 1.03 (↑ 30), 1.10 (↑ 30), 1.24 (↑ 20), 1.34 (↑ 20), 1.48 (↑ 10), 1.58 (↑ 8), 2.05 (↑ 10) daughter radiations from Pr^{139} daughter radiations from Nd^{139} included in above listing	Pr^{141}(p, 3n) (StovB51)
Nd^{140}	3.3 d (WilkG49c)	☢ EC (BrowCI52) EC(K)/EC(L) 6 (BiryE60) Δ −84 (MTW)	A chem, excit, genet (WilkG49c) parent Pr^{140} (WilkG49c, BrowCI52)	γ Pr X-rays daughter radiations from Pr^{140}	Pr^{141}(p, 2n) (StovB51) Pr^{141}(d, 3n) (WilkG49c, BrowCI52)
Nd^{141}	2.42 h (WilkG49c) 2.5 h (KurbJ42) 2.6 h (BiryE63) others (WilleR60)	☢ EC 96%, β^+ 4% (BiryE63) EC 98%, β^+ 2% (PolH58) others (AlfWL63) Δ −84.27 (MTW)	A excit (KurbJ42) chem, excit (WilkG49c) others (PoolM38a)	β^+ 0.79 max γ Pr X-rays, 0.145 (0.2%), 0.511 (6%, $\gamma^{\pm}$), 1.14 (2%, complex?), 1.30 (1%)	Pr^{141}(p, n) (KurbJ42, WilkG49c) Pr^{141}(d, 2n) (WilkG49c, PolH58)
Nd^{141m}	64 s (JameR60) 61 s (KotK60)	☢ [IT] (KotK60) Δ −83.52 (LHP, MTW)	C excit (JameR60) chem (KotK60)	γ 0.755	Pr^{141}(p, n) (JameR60)
Nd^{142}		% 27.13 (IngM48a) 27.09 (WalkW53) 27.3 (WhiF56) Δ −86.01 (MTW) σ_c 17 (GoldmDT64)			
Nd^{143}		% 12.20 (IngM48a) 12.14 (WalkW53) 12.32 (WhiF56) Δ −84.04 (MTW) σ_c 330 (GoldmDT64)			
Nd^{144}	2.4 × 10^{15} y sp act (MacfR61a) 2.1 × 10^{15} y sp act (IsolA65) 5 × 10^{15} y sp act (PorsW56, PorsW54) 2 × 10^{15} y sp act (WaldE54)	☢ α (WaldE54, PorsW54, PorsW56) % 23.87 (IngM48a) 23.83 (WalkW53) 23.8 (WhiF56) others (IngM50a) Δ −83.80 (MTW) σ_c 5 (GoldmDT64)	A sep isotopes, decay charac, chem (PorsW56, MacfR61a)	α 1.83	
Nd^{145}	$t_{1/2}$ (α) >6 × 10^{16} y (IsolA65)	% 8.29 (WhiF56, WalkW53) 8.30 (IngM48a) Δ −81.47 (MTW) σ_c 50 (GoldmDT64)			
Nd^{146}		% 17.18 (IngM48a) 17.26 (WalkW53) 17.1 (WhiF56) others (IngM50a) Δ −80.96 (MTW) σ_c 2 (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}≡0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{60}\mathrm{Nd}^{147}$	11.06 d (WriH57) 11.02 d (HoffD63) 11.1 d (AlsJ60) others (KondE51a, RutW52, MarinJ51, EmmW51, BotW46a)	☢ β^- (MarinJ47, MarinJ51) Δ −78.18 (MTW)	A chem, genet (MarinJ47, MarinJ51a) parent Pm^{147} (MarinJ47, MarinJ51a) daughter Pr^{147} (HoffD64)	β^- 0.81 max e^- 0.046, 0.084 γ 0.091 (28%), 0.319 (3%), 0.43 (4%, complex), 0.533 (13%) daughter radiations from Pm^{147}	Nd^{146}(n, γ) (BotW46a, MarinJ47, CorkJ48a, MarinJ51c) fission (MarinJ51)
$\underline{\mathrm{Nd}^{148}}$		% 5.72 (IngM48a) 5.74 (WalkW53) 5.67 (WhiF56) others (IngM50a) Δ −77.44 (MTW) σ_c 4 (GoldmDT64)			
Nd^{149}	1.8 h (RutW52, WilleR60, HoffD64) 2.0 h (BotW46a, PoolM38a) others (MarinJ51c)	☢ β^- (PoolM38a) Δ −74.41 (MTW)	A excit (PoolM38a) chem, genet (MarinJ51c) parent Pm^{149} (KruP52, MarinJ51c)	β^- 1.5 max e^- 0.051, 0.068, 0.079, 0.090, 0.165, 0.195 γ Pm X-rays, 0.114 (18%), 0.156 (4%), 0.210 (27%), 0.27 (26%, complex), 0.327 (5%), 0.424 (9%), 0.541 (10%), 0.654 (9%) daughter radiations from Pm^{149}	Nd^{148}(n, γ) (PoolM38a, BotW46a, MarinJ51c, GopK64)
$\underline{\mathrm{Nd}^{150}}$	$t_{1/2}$ (β) >10^{16} y sp act (DixD54a) $t_{1/2}$ ($\beta\beta$) >2 x 10^{18} y sp act (CowC56) others (MulhG52)	% 5.60 (IngM48a) 5.63 (WalkW53) 5.56 (WhiF56) others (IngM50a) Δ −73.67 (MTW) σ_c 1.5 (GoldmDT64)			
Nd^{151}	12 m (RutW52, MarinJ51c) others (WilleR60)	☢ β^- (RutW52) Δ −71.0 (MTW)	B n-capt (MarinJ51c) sep isotopes, n-capt, atomic level spacing (RutW52) parent Pm^{151} (RutW52)	β^- 2.0 max e^- 0.072 γ Pm X-rays, 0.086 (5%), 0.118 (40%), 0.138 (6%), 0.174 (10%, complex), 0.256 (11%), 0.425 (5%), 0.737 (5%), 0.797 (3%), 1.122 (2%), 1.180 (9%)	Nd^{150}(n, γ) (RutW52, MarinJ51c, SchmL59a, FosD65)
$_{61}\mathrm{Pm}^{141}$	22 m (GratI59) 20 m (FiscV52)	☢ β^+ 57%, EC 43% (GratI59) Δ −80.7 (MTW)	A chem, excit (FiscV52) mass spect (GratI59)	β^+ 2.6 max γ Nd X-rays, 0.195 (13%), 0.511 (114%, $\gamma^\pm$) daughter radiations from Nd^{141}	Pr^{141}(α, 4n) (GratI59) Nd^{142}(p, 2n) (FiscV52)
Pm^{142}	40 s (GratI59) others (MarsT58)	☢ β^+ ≈95%, EC ≈5% (GratI59) Δ −81.2 (MTW)	B chem, genet (MarsT58) excit (GratI59) daughter Sm^{142} (MarsT58)	β^+ 3.78 max (MarsT58) γ Nd X-rays, 0.511 (190%, $\gamma^\pm$)	Nd^{142}(α, 4n)Sm^{142}(EC) (GratI59, MarsT58) Nd^{142}(p, n) (GratI59)
Pm^{143}	0.73 y (PagI63, BunnL64, FunE60) 0.78 y (WilkG50e)	☢ EC (WilkG50e) Δ −82.9 (MTW)	A chem, excit (WilkG50e) chem, mass spect (BallN58)	γ Nd X-rays, 0.742 (47%) e^- 0.698	Sm^{144}(p, 2n)[Eu^{143}](EC) Sm^{143}(EC) (FunE60) Pr^{141}(α, 2n) (WilkG50e, FiscV52, OfeS59, BunnL64) Nd^{143}(p, n) (PagI63)
Pm^{144}	0.96 y (BunnL64) 1.03 y (PagI63) 1.1 y (FunE60) 1.2 y (TotK59c) others (FiscV52)	☢ EC (FiscV52) no β^+, lim 0.2% (OfeS59) Δ −82 (MTW)	A chem (FiscV52) chem, mass spect (BallN58) excit (OfeS59)	γ Nd X-rays, 0.474 (45%), 0.615 (99%), 0.695 (99%) e^- 0.430, 0.571, 0.651	Pr^{141}(α, n) (OfeS59, TotK59c, FiscV52) Nd^{144}(p, n) (PagI63, SugiyK61, FiscV52)
$\mathrm{Pm}^{144?}$	60 d (PagI63)	☢ (PagI63)	F sep isotopes (PagI63)	γ γ spectrum may be identical to 1.1 y Pm^{144} (PagI63)	Nd^{144}(p, n) (PagI63)
Pm^{145}	17.7 y (BrosA59) others (ButeF51)	☢ EC (ButeF51) α 3 x 10^{-7}% (NurM62) Δ −81.33 (MTW)	A chem, genet (ButeF51) chem, mass spect (BallN58) daughter Sm^{145} (ButeF51)	γ Nd X-rays, 0.067 (1.0%), 0.072 (2.3%) e^- 0.023, 0.028, 0.061	Sm^{144}(n, γ)Sm^{145}(EC) (ButeF51, BrosA59)
Pm^{145}	16 d (LongJ52a)	☢ β^+ (LongJ52a)	F sep isotopes (LongJ52a)	β^+ 0.45 max	protons on Nd (LongJ52a)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12} ≡ 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{61}$Pm^{146}	4.4 y (PagI63) 1.9 y (FunE60) 1 y (FiscV52) 1-2 y (LongJ52a)	☢ EC 65%, β$^-$ 35% (FunE60) EC 69%, β$^-$ 31% (PagI63) Δ −79.52 (MTW)	A chem, excit (FiscV52) chem, sep isotopes, genet energy levels (FunE60, FunE62)	β$^-$ 0.78 max γ Nd X-rays, 0.453 (65%), 0.75 (65%, doublet)	Nd^{146}(p, n) (PagI63, FiscV52, LongJ52a) Nd^{148}(p, 3n) (FunE60)
Pm^{147}	2.62 y (WheeE65) 2.60 y (FlyK65a) 2.64 y (MerW57) 2.66 y (SchumR56) others (MelaE55, IngM50a, SchumR51a)	☢ β$^-$ (BallN51g) Δ −79.08 (MTW) σ$_c$ 120 (to Pm^{148}) 110 (to Pm^{148m}) (GoldmDT64)	A chem (MarinJ47, MarinJ51a) mass spect (HaydR48) daughter Nd^{147} (MarinJ47, MarinJ51a) parent Sm^{147} (RasJ50)	β$^-$ 0.224 max average β$^-$ energy: 0.070 calorimetric (HovV62) γ no γ	Nd^{146}(n, γ)Nd^{147}(β$^-$) (MarinJ47, MarinJ51a) fission (BallN51g, SeiJ51c, MarinJ51a, GrumW48, IngM50a)
Pm^{148}	5.4 d (ReicC62, EldJ61) others (SchweC62a, ParkG47, KurbJ43, BhaS59)	☢ β$^-$ (KurbJ43) Δ −76.89 (BabC63a, MTW) σ$_c$ ≈2000 (GoldmDT64)	A chem, n-capt, mass spect (ParkG47) daughter Pm^{148m} (BabC63a)	β$^-$ 2.48 max γ 0.551 (27%), 0.914 (15%), 1.465 (23%)	Nd^{148}(p, n) (LongJ52, FiscV52, KurbJ43, SchweG62a) Nd^{148}(d, 2n) (KurbJ42, KurbJ43, BabC63a) Pm^{147}(n, γ) (ParkG47, ReicC62)
Pm^{148m}	41.8 d (EldJ61) 40.6 d (ReiC62) 45.5 d (SchweC62a) others (FiscV52, FolR51, LongJ52)	☢ β$^-$ 93%, IT 7% (BabC63a) others (ReiC62, SchweC62a) Δ −76.75 (LHP, MTW) σ$_c$ 30,000 (GoldmDT64)	A excit, sep isotopes (LongJ52) chem (FolR51) chem, mass spect, genet (BabC63a) parent Pm^{148} (BabC63a)	β$^-$ 0.69 max e$^-$ 0.031, 0.053, 0.091, 0.242, 0.503, 0.583 γ Pm X-rays, Sm X-rays, 0.289 (13%), 0.413 (17%), 0.551 (95%), 0.630 (87%), 0.727 (36%), 0.916 (21%), 1.015 (20%) daughter radiations from Pm^{148}	Nd^{148}(p, n) (LongJ52, FiscV52, SchweC62a) Nd^{148}(d, 2n) (BabC63a) Pm^{147}(n, γ) (ReiC62)
Pm^{149}	53.1 h (HoffD63, BunnL60) others (ArtnA60, FiscV52, IngM47d, RutW52, KondE51c, BotW46a, MarinJ51b)	☢ β$^-$ (MarinJ47) Δ −76.07 (MTW)	A chem (MarinJ47, MarinJ51b) chem, mass spect (IngM47d) daughter Nd^{149} (KruP52, MarinJ51c)	β$^-$ 1.07 max γ 0.286 (2%), 0.58 (0.1%), 0.85 (0.2%)	Nd^{148}(n, γ)Nd^{149}(β$^-$) (KruP52, MarinJ47, SchmL60a, BunnL60)
Pm^{150}	2.68 h (FiscV52) 2.7 h (LongJ52)	☢ β$^-$ (LongJ52) Δ −73.6 (MTW)	A excit, sep isotopes (LongJ52) chem, excit, sep isotopes (FiscV52)	β$^-$ 3.05 max γ 0.334 (71%), 0.406 (7%), 0.71 (8%), 0.831 (18%), 0.88 (12%), 1.165 (23%), 1.33 (22%), 1.75 (10%), 1.96 (2.5%), 2.06 (1.2%), 2.53 (0.9%)	Nd^{150}(p, n) (LongJ52, FiscV52)
Pm^{151}	27.8 h (HoffD63) 28.4 h (BunnL60) 27.5 h (RutW52)	☢ β$^-$ (RutW52) Δ −73.40 (MTW)	A genet, atomic level spacing (RutW52) chem (BunnL60) daughter Nd^{151} (RutW52)	β$^-$ 1.19 max e$^-$ 0.003, 0.018, 0.053, 0.058 γ Sm X-rays, 0.07 (5%, complex), 0.10 (7%, doublet), 0.17 (18%, complex), 0.24 (5%, complex), 0.275 (6%), 0.340 (21%), 0.45 (5%, complex), 0.66 (3%, complex), 0.72 (6%, complex), others to 0.96	Nd^{150}(n, γ)Nd^{151}(β$^-$) (RutW52, BunnL60)
Pm$^{?}$	12.5 h (FolR51, (PoolM38a)	☢ β$^-$ (PoolM38a)	E (PoolM38a) chem (FolR51)		deuterons on Nd (PoolM38a) fission (FolR51)
Pm^{152}	6.5 m (WilleR58, WilleR60)	☢ β$^-$ (WilleR58) Δ −71 (MTW)	B sep isotopes, excit (WilleR58) genet energy levels (AteA59)	β$^-$ 2.2 max γ [Sm X-rays], 0.122, 0.245	Sm^{152}(n, p) (WilleR58, WilleR60, AteA59)
Pm^{153}	5.5 m (KotK62)	☢ β$^-$ (KotK62) Δ −70.8 (MTW)	E excit, sep isotopes (KotK62)	β$^-$ 1.65 max γ 0.090 (?), 0.12, 0.18	Sm^{154}(γ, p) (KotK62)
Pm^{154}	2.5 m (WilleR58, WilleR60)	☢ β$^-$ (WilleR60)	C excit, sep isotopes (WilleR58)	β$^-$ 2.5 max	Sm^{154}(n, p) (WilleR58, WilleR60)
$_{62}$Sm^{142}	73 m (GratI59) 72 m (MarsT58)	☢ EC ≈50%, β$^+$ ≈50% (DCapG59)	B chem (MarsT58) excit (GratI59) parent Pm^{142} (MarsT58)	γ Pm X-rays, 0.15-0.35 (complex), 0.511 (100%, γ$^±$) daughter radiations from Pm^{142}	Nd^{142}(α, 4n) (GratI59, MarsT58)
Sm^{143}	9.0 m (SilE56) 8.9 m (AlfWL63a) 8.6 m (GratI59) 8.5 m (WilleR60) 8.3 m (MirM56) 8.8 m (KotK60) others (ButeF50)	☢ EC 52%, β$^+$ 48% (DCapG59) EC ≈63%, β$^+$ ≈37% (GratI59) others (SilE56, MirM56) Δ −79.6 (MTW)	B chem (ButeF50) excit (SilE56) chem, sep isotopes (MirM56)	γ Pm X-rays, 0.511 (100%, γ$^±$)	Nd^{142}(α, 3n) (GratI59) Sm^{144}(n, 2n) (WilleR60, MirM56, AlfWL63a) Sm^{144}(γ, n) (SilE56, ButeF50, KotK60, DCapG59)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{62}Sm^{143m}$	64 s (KotK60) 65 s (AlfWL63a) 61 s (BroaK65) others (JameR60)	☢ [IT] (KotK60) Δ −78.8 (LHP, MTW)	C chem (KotK60) excit (AlfWL63a)	γ 0.748	Sm^{144}(n, 2n) (AlfWL63a) Sm^{144}(γ, n) (KotK60) Sm^{144}(p, pn) (JameR60)
Sm^{144}		% 3.16 (IngM48) 3.15 (CollT57) 3.02 (AitK57) Δ −81.98 (MTW) σ_c ≈0.7 (GoldmDT64)			
Sm^{145}	340 d (BrosA59) others (ButeF51, CorkJ48a, IngM47c)	☢ EC (ButeF51, RutW52) Δ −80.67 (MTW) σ_c ≈100 (GoldmDT64)	A mass spect (IngM47c) chem (ButeF51) parent Pm^{145} (ButeF51)	γ Pm X-rays, 0.061 (13%), 0.485 (3×10^{-3}%) e^- 0.016, 0.054 daughter radiations from Pm^{145}	Sm^{144}(n, γ) (ButeF51, RutW52, IngM47c, BrosA59)
Sm^{146}	7×10^7 y sp act (NurM64) 5×10^7 y yield (DunlD53)	☢ α (DunlD53) % $<2 \times 10^{-7}$ (MacfR60) Δ −81.05 (MTW)	B chem, decay charac (DunlD53)	α 2.46	Sm^{147}(n, 2n) (NurM64) alphas on Nd (DunlD53)
Sm^{147}	1.05×10^{11} y sp act (WriP61) others (DonhD64, MacfR61a, GraeG61, BearG54, BearG58, KarrM60, KarrM60a, LatC47, HosR35, PicE49)	☢ α (HevG32, LibW33) % 15.07 (IngM48) 15.1 (CollT57) 14.9 (AitK57) Δ −79.30 (MTW) σ_c ≈90 (GoldmDT64)	A chem (HevG32) sep isotopes, mass spect WeaB50) chem, genet, mass spect (RasJ50) daughter Pm^{147} (RasJ50)	α 2.23	
Sm^{148}	$t_{1/2}$ (α) $>2 \times 10^{14}$ y sp act (MacfR61a) $t_{1/2}$ (α) 1.2×10^{13} y sp act (KarrM60)	% 11.27 (IngM48) 11.35 (CollT57) 11.22 (AitK57) ☢ no α (MacfR61a) α (KarrM60) Δ −79.37 (MTW)			
Sm^{149}	>1 x 10[illegible] y sp act (MacfR61a) 4×10^{14} y sp act (KarrM60)	% 13.82 (AitK57) 13.84 (IngM48) 14.0 (CollT57) ☢ no α (MacfR61a) α (KarrM60) Δ −77.15 (MTW) σ_c 41, 500 (GoldmDT64)			
Sm^{150}		% 7.47 (IngM48, CollT57) 7.40 (AitK57) Δ −77.06 (MTW) σ_c 100 (GoldmDT64)			
Sm^{151}	≈87 y (FlyK65a) ≈93 y yield + mass spect (MelaE55) ≈73 y (KarrD52) ≈120 y yield (IngM50a)	☢ β^- (IngM47c) Δ −74.59 (MTW) σ_c 15, 000 (GoldmDT64)	A mass spect (IngM47c, IngM50a) chem (MarinJ49a)	β^- 0.076 max e^- 0.014, 0.020 γ Eu L X-rays, 0.022 (4%)	fission (IngM50a, MarinJ49a, AchW59) Sm^{150}(n, γ) (IngM47c)
Sm^{152}		% 26.63 (IngM48) 26.6 (CollT57) 26.8 (AitK57) Δ −74.75 (MTW) σ_c 210 (GoldmDT64)			
Sm^{153}	46.8 h (WyaE61) 47.1 h (CorkJ58, CabM62) 46.2 h (GreeRE61) 46.5 h (HoffD63) 47.0 h (LeeM54) others (KurbJ42, BotW46a, WinsL51, RutW52)	☢ β^- (KurbJ42) Δ −72.56 (MTW)	A n-capt, excit (PoolM38a) mass spect (HaydR46, IngM47d) chem (WinsL51)	β^- 0.80 max e^- 0.022, 0.055, 0.062, 0.095, 0.101 γ Eu X-rays, 0.070 (5.4%), 0.103 (28%), 0.41 to 0.64 (0.6%, 16 γ rays)	Sm^{152}(n, γ) (HevG36, PoolM38a, HaydR46, SerL47b, WinsL51) Nd^{150}(α, n) (KurbJ42)
Sm^{154}		% 22.53 (IngM48) 22.4 (CollT57) 22.9 (AitK57) others (IngM50a) Δ −72.39 (MTW) σ_c 5 (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{62}$Sm^{155}	23.5 m (RutW52) 21.9 m (SunR60) others (WinsL51a, PoolM38a)	☢ β^- (KurbJ42) Δ −70.14 (MTW)	A n-capt (AmaE35, MarsJK35) chem (WinsL51a) sep isotopes (SunR60, SchmL59b) parent Eu^{155} (IngM47c)	β^- 1.53 max e^- 0.056, 0.097, 0.103 γ Eu X-rays, 0.104 (73%), 0.246 (4%)	Sm^{154}(n,γ) (AmaE35, MarsJK35, HevG36, PoolM38a, SerL47b, IngM47c, WinsL51a, SunR60, SchmL59b)
Sm^{156}	9.4 h (GunR63) 9 h (AlsJ60)	☢ β^- (WinsL51c) Δ −69.33 (MTW)	B chem, genet (WinsL51c) parent Eu^{156} (WinsL51c)	β^- 0.72 max e^- 0.014, 0.021, 0.030, 0.039 γ Eu X-rays, 0.088 (30%), 0.166 (10%), 0.204 (20%), 0.25 (5%, complex), 0.291 (3%) daughter radiations from Eu^{156}	fission (WinsL51c, AlsJ60, GunR63)
Sm^{157}	0.5 m (WilleR60)	☢ [β^-] (WilleR60)	C sep isotopes, cross bomb (WilleR60)	γ 0.57	Gd^{160}(n, α) (WilleR60)
$_{63}$Eu^{143}	2.3 m (KotK65)	☢ β^+ (KotK65), [EC]	E excit, decay charac (KotK65)	β^+ 4.0 max γ 0.511 (γ±)	Sm^{144}(d, 3n) (KotK65)
Eu^{144}	10.5 s (MesR65)	☢ β^+ (MesR65), [EC] Δ −75.66 (MesR65, MTW)	C excit, decay charac (MesR65)	β^+ 5.2 max γ 0.511 (γ±)	Sm^{144}(p, n) (MesR65)
Eu^{144}	18 m (HoffR52)	☢ β^+ (HoffR52)	G excit, sep isotopes (HoffR52) activity not observed (OlkJ59b, MesR65)		protons on Sm^{144} (HoffR52)
Eu^{145}	5.9 d (FrieA63) 5.6 d (GrovJ59) others (HoffR51)	☢ EC 99%, β^+ 1% (FrieA63) Δ −77.9 (MTW)	A chem, excit, sep isotopes (GrovJ59) chem, mass spect (FrieA63) daughter Gd^{145} (GrovJ59) daughter Tb^{149} (HoffR51)	γ Sm X-rays, 0.23?, 0.33?, 0.53 (complex), 0.656 (! 30), 0.766 (! 10), 0.894 (! 100), 1.66 (! 16), 2.00 (! 8) e^- 0.063, 0.103, 0.847 daughter radiations from Sm^{145}	Sm^{144}(α, 3n)Gd^{145}(EC) (GrovJ59, OlkJ59b, FrieA63) Sm^{144}(d, n) (GrovJ59)
Eu^{146}	4.59 d (TakekE64) others (FrieA63, GrovJ59, FunE62, GoroG58, AntoN59a, GoroG57a)	☢ EC 96.5%, β^+ 3.5% (FunE62) EC 95.5%, β^+ 4.5% (TakekE64) others (FrieA63) Δ −77.18 (MTW)	A chem, genet (GoroG57a, GoroG58, GrovJ59) chem, mass spect (FrieA63) daughter Gd^{146} (GoroG58, GrovJ59)	γ Sm X-rays, 0.511 (7%, γ±), 0.634 (77%, doublet), 0.666 (12%), 0.71 (13%, complex), 0.749 (100%), 0.90 (8%, complex), 1.058 (7%), 1.16 (6%, complex), 1.298 (6%), 1.408 (5%), 1.535 (8%), others to 2.93 β^+ 2.11 max (0.14%), 1.47 max (3.3%) e^- 0.586, 0.702	Sm^{144}(α, 2n)Gd^{146}(EC) (GrovJ59, FrieA63)
Eu$^{146?}$	38 h (HoffR51) others (FunE62,	☢ (HoffR51)	E excit, sep isotopes (HoffR51) chem (FunE62) not daughter 50 d Gd^{146} (FrieA63, AntoN61) daughter 7 h Gd$^{146?}$ (GuseI57)	γ γ-ray spectrum may be identical to that of 4.59 d Eu^{146}	Sm^{147}(d, 3n), alphas on Sm^{144} (HoffR51) Sm^{147}(p, 2n) (FunE62)
Eu^{147}	21.5 d (FrieA63) 24 d (SchweC62, HoffR51, RasJ53, MackRC53) 25 d (AntoN58c)	☢ EC 99.5%, β^+ 0.5% (MNulJ64) α 0.002% (SiiA62, TotK64) others (HoffR51, FrieA63) Δ −77.5 (MTW)	A chem, excit, sep isotopes (HoffR51) chem, mass spect (FrieA63) daughter Gd^{147} (GoroG57a)	γ Sm X-rays, 0.122 (20%), 0.198 (24%), 0.600 (7%), 0.680 (11%), 0.800 (6%), 0.957 (9%), 1.079 (9%), 1.25 (1.2%) e^- 0.030, 0.075, 0.114, 0.151 α 2.91	Sm^{147}(p, n) (HoffR51, RasJ53, SchweC62) Sm^{148}(p, 2n) (MNulJ64) deuterons on Sm (RasJ53)
Eu^{148}	54 d (WilkG50c) 50 d (HoffR51) 58 d (SchweC62a) 53 d (MarinJ51d)	☢ EC 99+%, β^+ 0.13% (BabC63b) α 9 x 10^{-7}% (TotK64) Δ −76.26 (BabC63b, MTW)	A chem (MarinJ51d) excit, sep isotopes (HoffR51, MackRC52) mass spect (BabC63b)	γ Sm X-rays, 0.413 (18%, complex), 0.551 (120%, complex), 0.62 (90%, complex), 0.72 (18%, complex), 0.872 (7%), 0.917 (5%), 0.967 (5%), 1.033 (7%), 1.16 (5%, complex), 1.345 (8%), 1.62 (11%, complex) e^- 0.02-0.04, 0.51, 0.193, 0.366, 0.505, 0.544, 0.584 β^+ 0.92 max α 2.63	Sm^{148}(p, n) (HoffR51, MackRC52, WilkG50c, SchweC62a) Sm^{147}(d, n) (KurbJ43, MarinJ51d) Sm^{148}(d, 2n) (BabC63b)
Eu^{149}	106 d (HarlO61) others (AntoN59, DzhB62d, WanF62)	☢ EC (HarlO61, HarmB61, AntoN59) no α, lim 4 x 10^{-7}% (SiiA62) Δ −76 (MTW)	A sep isotopes, excit (HoffR52) chem, excit (MackRC53, HarlO61, HarlO63) genet energy levels (JhaS62b, AlfV64)	γ Sm X-rays, 0.277 (! 10), 0.328 (! 10) e^- 0.015, 0.021, 0.230, 0.281	Sm^{149}(p, n) (HoffR52, HarlO61, HarlO63) Sm^{150}(p, 2n) (HarmB61, HarlO61)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{63}$Eu^{150}	12.55 h (SiiA62) 12.8 h (YosY63) 13.7 h (MackRC53) 14.0 h (RiccR62) 15.0 h (WilkG50c) others (WilleR60, ButeF50)	☢ β^- 90%, EC 9%, β^+ 0.4% (GutM65) β^- 95%, EC 4%, β^+ 1% (YosY63) β^- 95%, EC 5% (SiiA62) Δ -74.81 (MTW)	A chem, excit (ButeF50) chem, excit, sep isotopes (HoffR52) excit, sep isotopes (MackRC52) parent Gd^{150} (KarrM61, SiiA62)	β^- 1.01 max β^+ 1.24 max γ Sm X-rays, 0.334 (4%), 0.406 (3%), 0.511 (0.8%, γ$^{\pm}$), 0.619 (0.2%), 0.713 (0.2%), 0.831 (0.5%), 0.921 (0.4%, doublet), 1.165 (0.4%), 1.224 (0.4%), 1.224 (0.3%), 1.630 (0.09%), 1.964 (0.2%)	Sm^{150}(p.n) (HoffR52, MackRC52, WilkG50c, HarmB61, YosY63) Sm^{150}(d, 2n) (YosY63)
Eu^{150}	≈5 y (GutM61) >5 y (HarmB61)	☢ EC (HarmB61, GutM61)	A chem, genet energy levels (HarmB61, GutM61)	γ Sm X-rays, 0.334 (96%), 0.439 (86%), 0.584 (60%), 0.74 (21%, doublet), 1.049 (9%), 1.248 (5%), 1.347 (4%) e$^-$ 0.287, 0.327, 0.392	Sm^{150}(p, n) (HarmB61, GutM61)
Eu^{151}		% 47.77 (HessD48) 47.86 (CollT57) Δ -74.67 (MTW) σ_c 5900 (to Eu^{152}) 2800 (to Eu^{152m_1}) (GoldmDT64)			
Eu^{152}	12.7 y (LocE56, LocE53) 12.2 y (GeiKW57) others (KarrD52, KasJ53)	☢ EC 72%, β^- 28%, β^+ 0.021% (LHP) Δ -72.89 (MTW) σ_c 5000 (GoldmDT64)	A n-capt, mass spect (IngM47) chem (MarinJ49)	β^- 1.48 max e$^-$ 0.075, 0.115, 0.120 β^+ 0.71 max γ Gd X-rays, Sm X-rays, 0.122 (37%), 0.245 (8%), 0.344 (27%), 0.779 (14%), 0.965 (15%), 1.087 (12%), 1.113 (14%), 1.408 (22%)	Eu^{151}(n, γ) (IngM47, SerL47b)
Eu^{152m_1}	9.3 h (BotW46a, ChilG61a) 9.2 h (PoolM38a, HaydR49, AntoS59	☢ β^- 77%, EC 23%, β^+ 0.011% (NDS) no IT, lim 0.003% (TakaK65) Δ -72.84 (LHP, MTW)	A n-capt (MarsJK35) n-capt, excit (PoolM38a) mass spect (HaydR46, HaydR49)	β^- 1.88 max e$^-$ 0.075, 0.115, 0.120 β^+ 0.89 max γ 0.122 (8%), 0.344 (2.5%), 0.842 (13%), 0.963 (12%), 1.315 (1.2%), 1.389 (1.1%)	Eu^{151}(n, γ) (MarsJK35, PoolM38a, HevG36, FajK41, SerL47b, HaydR49)
Eu^{152m_2}	96 m (KirP63)	☢ IT (KirP63) no β^-, no EC, lim 5% (KirP63) Δ -72.74 (LHP, MTW)	A chem, excit, sep isotopes, cross bomb (KirP63)	γ Eu X-rays, 0.090 (74%) e$^-$ 0.010, 0.016, 0.032, 0.039	Sm^{154}(p, 3n) (KirP63) Sm^{152}(p, n) (KirP63) Eu^{151}(n, γ) (TakaK65)
Eu^{153}		% 52.23 (HessD48) 52.14 (CollT57) Δ -73.36 (MTW) σ_c 320 (GoldmDT64)			
Eu^{154}	16 y (KarrD52) others (HaydR49, GeiKW57, KasJ53)	☢ β^- (HaydR49) no β^+, lim 0.003% (AlbuD58b) Δ -71.68 (MTW) σ_c 1400 (GoldmDT64)	A n-capt (ScheiH38) mass spect (IngM47, HaydR49) chem (KarrD52)	β^- 1.85 max (10%), 0.87 max e$^-$ 0.073, 0.115, 0.122 γ Gd X-rays, 0.123 (38%), 0.248 (7%), 0.593 (6%), 0.724 (21%), 0.759 (5%), 0.876 (12%), 1.00 (31%, doublet), 1.278 (37%)	Eu^{153}(n, γ) (ScheiH38, FajK39, FajK41a, SerL47b)
Eu^{155}	1.811 y (PierrA59) others (RutW52, WinsL51d, HaydR49)	☢ β^- (WinsL51d) Δ -71.79 (MTW) σ_c 13,000 (GoldmDT64)	A chem (WinsL51d) mass spect (HaydR49) daughter Sm^{155} (IngM47c)	β^- 0.25 max e$^-$ 0.011, 0.017, 0.036, 0.054, 0.078, 0.082 γ Gd X-rays, 0.087 (32%), 0.105 (20%)	Sm^{154}(n, γ)Sm^{155}(β^-) (IngM47c)
Eu^{156}	15.4 d (WinsL51c, IngM47c)	☢ β^- (WinsL51c) Δ -70.05 (MTW)	A chem (WinsL51c) mass spect (IngM47d, IngM47c) daughter Sm^{156} (WinsL51c)	β^- 2.45 max e$^-$ 0.039, 0.081, 0.087 γ Gd X-rays, 0.089 (8%), 0.646 (7%), 0.723 (6%), 0.812 (9%), 1.07 (11%, complex), 1.15 (14%, complex), 1.24 (16%, complex), 1.97 (7%, complex), 2.098 (3%), 2.19 (5%, complex)	Sm^{154}(n, γ)Sm^{155}(β^-) Eu^{155}(n, γ) (EwaG62, CliJ61) daughter Sm^{156} (WinsL51c)
Eu^{157}	15.1 h (DaniW63) 15.4 h (WinsL51b)	☢ β^- (WinsL51b) Δ -69.43 (LHP, MTW)	A chem (WinsL51b) genet energy levels (HarmB62) cross bomb (DaniW63) sep isotopes (ShidY64)	β^- 1.3 max e$^-$ 0.004, 0.014, 0.046, 0.056 γ Gd X-rays, 0.055 (5%), 0.064 (27%), 0.32 (5%, doublet), 0.37 (14%, doublet), 0.413 (27%), 0.477 (5%), 0.623 (6%)	Gd^{160}(p, α) (HarmB62) neutrons on Gd (KantJ64)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12} = 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{63}$Eu^{158}	46 m (MunH65, SchimF65a, DaniW63) 60 m (WinsL51b)	☢ β^- (WinsL51b) Δ −67.1 (MTW)	B chem (WinsL51b) chem, genet energy levels (DaniW63)	β^- 2.5 max e$^-$ [0.049, 0.072] γ 0.080 (↑ 100), 0.182, 0.52 (↑ 25, complex), 0.61 (↑ 8), 0.95 (↑ 95, complex), 1.11 (↑ 11), 1.19 (↑ 16)	Gd^{160}(d, α) (DaniW63) fission (WinsL51b)
Eu^{159}	18.1 m (MunH65) 19.0 (IwaT65) others (IwaT64, ButeF50, KuroT61b)	☢ β^- (KuroT61b) Δ −66.02 (IwaT65, MTW)	C excit (ButeF50) sep isotopes, genet (IwaT64) parent Gd^{159} (IwaT64)	β^- 2.6 max γ 0.07 (42%), 0.09 (18%), 0.15 (14%), 0.22 (5%), 0.67 (21%), 0.73 (10%), 0.8 (11%, complex?), 1.1 (11%, complex), 1.5 (5%, complex?)	Gd^{160}(γ, p) (IwaT64, KuroT61b, ButeF50)
Eu^{160}	≈2.5 m (TakaK61)	☢ β^- (TakaK61) Δ −64 (MTW)	F decay charac (TakaK61)	β^- 3.6 max γ no γ	Gd^{160}(n, p) (TakaK61)
$_{64}$Gd^{145}	25 m (GrovJ59) others (OlkJ59b)	☢ EC, β^+ (GrovJ59, OlkJ59b)	A chem, excit, sep isotopes, genet (GrovJ59) parent Eu^{145} (GrovJ59)	β^+ 2.4 max γ Eu X-rays, 0.511 (γ$^{\pm}$), 0.80 (↑ 9), 1.03 (↑ 10), 1.75 (↑ 100, complex?)	Sm^{144}(α, 3n) (GrovJ59, OlkJ59b)
Gd^{146}	50 d (FrieA63) 46 d (GrovJ59) others (AntoN59a, GoroG58, GoroG57a, OlkJ59)	☢ EC (GoroG58) EC ≈99%, β^+ ≈1% (FrieA63) Δ −76 (MTW)	A chem, genet (GoroG57a, GoroG58) chem, excit, sep isotopes (GrovJ59) chem, mass spect (FrieA63) parent Eu^{146} (GoroG58, GrovJ59)	γ Eu X-rays, 0.078 (↑ 30), 0.115 (↑ 100, complex), 0.155 (↑ 45) e$^-$ 0.066, 0.106 daughter radiations from 4.59 d Eu^{146}	Sm^{144}(α, 2n) (GrovJ59, FrieA63)
Gd$^{146?}$	7 h (OlkJ59, SunK51a) 12 h genet (GuseI57)	☢ α (SunK51a) α, [EC] (OlkJ59)	F chem (GuseI57, OlkJ57) parent 38 h Eu$^{146?}$ (GuseI57)	γ 0.22, 0.34, 0.55, 0.72	alphas on Sm (SunK51a) protons on Tb (OlkJ59) protons on Ta (GuseI57)
Gd^{147}	35 h (AntoN58c) 22 h (FrieA63) 29 h (ShirV57)	☢ EC, no β^+, lim 1.2% (ShirV57) β^+ (weak) (FrieA63) Δ −75 (MTW)	A chem, genet (GoroG57a) chem, excit (ShirV57) chem, mass spect (FrieA63) parent Eu^{147} (GoroG57a) daughter Tb^{147} (TotK60)	γ Eu X-rays, 0.229 (↑ 150), 0.39 (↑ 85, complex), 0.64 (↑ 70, complex), 0.77 (↑ 60, complex), 0.932 (↑ 60), 1.10 (↑ 19, complex) e$^-$ 0.181, 0.221, 0.321, 0.348, 0.388 daughter radiations from Eu^{147}	Sm^{144}(α, n) (FrieA63) Sm^{147}(α, 4n) (ShirV57)
Gd^{148}	84 y (SiiA62) others (RasJ53, SurY57)	☢ α (RasJ53) Δ −76.29 (MTW)	B chem, excit, sep isotopes (RasJ53)	α 3.18	Sm^{147}(α, 3n), Eu^{151}(p, 4n) (RasJ53)
Gd^{149}	9.5 d (PraH62a) 9.3 d (ShirV57) others (HoffR51, AntoN58b)	☢ EC 99+%, α ≈0.0007%, no β^+, lim 0.4% (ShirV57, RasJ53) α 0.0005% (SiiA65a) Δ −75.2 (MTW)	A chem, excit, sep isotopes, cross bomb (HoffR51) chem, excit (ShirV57) chem, sep isotopes (PraH62a)	γ Eu X-rays, 0.150 (48%), 0.299 (26%), 0.347 (25%), 0.750 (11%), 0.790 (10%), 0.94 (5%, complex) e$^-$ 0.101, 0.142, 0.250, 0.298 α 3.01 daughter radiations from Eu^{149}	Eu^{151}(p, 3n) (HoffR51, PraH62a) Sm^{147}(α, 2n) (RasJ53, ShirV57)
Gd^{150}	2.1 × 10^6 y sp act (SiiA62) 1.4 × 10^6 y sp act (OgaI65) 1.2 × 10^5 y sp act (FrieA63b) ≈1 × 10^5 y (KarrM61)	☢ α (RasJ53) Δ −75.82 (MTW)	A chem (RasJ53) mass spect (FrieA63b) daughter 12.6 h Eu^{150} (KarrM61, SiiA62)	α 2.73	daughter 12.6 h Eu^{150} (KarrM61, SiiA62) Eu^{151}(d, 3n) (RasJ53) alphas on Sm (FrieA63b)
Gd^{151}	120 d (AntoN58a) 150 d (HeiR50)	☢ EC, no β^+ (HeiR50) α ≈8 × 10^{-7}% (SiiA65a) Δ −74 (MTW)	A chem, excit (HeiR50) chem, genet energy levels (BisA57, ShirV58) daughter Tb^{151} (BaranV58)	γ Eu X-rays, 0.0216 (3%), 0.154 (7%), 0.175 (3%), 0.244 (7%), 0.308 (1%) e$^-$ 0.014, 0.020, 0.105, 0.127, 0.167 α 2.60	Eu^{151}(p, n) (ShirV58, SiiA65a) Eu^{151}(d, 2n) (FajK41, ShirV58, KriN48, HeiR50, SteicE63)
Gd^{152}	1.1 × 10^{14} y sp act (MacfR61a) ≈10^{15} y (RieW59)	% 0.20 (BaiK50) 0.21 (CollT57) ☢ α (RieW59, MacfR61a) Δ −74.71 (MTW) σ_c <180 (GoldmDT64)	A chem, sep isotopes (RieW59, MacfR61a)	α 2.1	

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{64}$Gd^{153}	242 d (HoffD63) 236 d (HeiR50)	☢ EC, no β^+ (HeiR50) Δ −73.12 (MTW)	A mass spect (IngM47c) chem, n-capt (HeiR50) daughter Tb^{153} (MihJ57a, BaraV58)	γ Eu X-rays, 0.070 (2.4%), 0.099 (55%, complex) e^- 0.021, 0.049, 0.065, 0.101	Gd^{152}(n, γ) (IngM47c, CorkJ48a, HeiR50) Eu^{153}(d, 2n) (HeiR50)
Gd^{154}		% 2.15 (BaiK50) 2.23 (CollT57) Δ −73.65 (MTW)			
Gd^{155}		% 14.7 (BaiK50) 15.1 (CollT57) 15.0 (LowW59) Δ −72.04 (MTW) σ_c 58, 000 (GoldmDT64)			
Gd^{156}		% 20.47 (BaiK50) 20.6 (CollT57) Δ −72.49 (MTW)			
Gd^{157}		% 15.68 (BaiK50) 15.7 (CollT57) others (LowW59) Δ −70.77 (MTW) σ_c 2.4 x 10^5 (GoldmDT64)			
Gd^{158}		% 24.9 (BaiK50) 24.5 (CollT57) Δ −70.63 (MTW) σ_c 3.4 (GoldmDT64)			
Gd^{159}	18.0 h (KriN48, ButeF50, ButeF49, BarlR55a, WilleR60) others (TotK60a, TakaK62, SerL47b)	☢ β^- (KriN48) Δ −68.59 (MTW)	A n-capt (SerL47b) chem (ButeF49, HeiR50) genet energy levels (JorW53a) mass spect (NielK58a) daughter Eu^{159} (IwaT64)	β^- 0.95 max e^- 0.006, 0.049, 0.056 γ Tb X-rays, 0.058 (3%), 0.363 (9%)	Gd^{158}(n, γ) (SerL47b, ButeF49, HeiR50)
Gd^{160}		% 21.9 (BaiK50) 21.6 (CollT57) Δ −67.89 (MTW) σ_c 0.8 (GoldmDT64)			
Gd^{161}	3.6 m (ButeF49) 3.7 m (JorW53a) others (KriN48, WilleR60)	☢ β^- (KetB49c) Δ −65.5 (MTW)	A n-capt (IngM46) n-capt, excit (ButeF49) n-capt, sep isotopes (SchmL59) parent Tb^{161} (KetB49c)	β^- 1.6 max e^- 0.005, 0.026, 0.049, 0.055, 0.263, 0.309 γ Tb X-rays, 0.102 (11%), 0.284 (8%), 0.315 (25%), 0.361 (66%)	Gd^{160}(n, γ) (IngM46, ButeF49, KetB49b, SchmL59)
Gd^{162}	several years (?) (FalK57)	☢ [β^-] (FalK57) Δ −64 (MTW)	F chem (FalK57) not parent Tb^{162} (FalK57)		Gd^{160}(n, γ) Gd^{161}(n, γ) (FalK57)
$_{65}$Tb^{147}	24 m (TotK60)	☢ EC, β^+ (TotK60)	C excit, genet (TotK60) parent Gd^{147} (TotK60)	γ Gd X-rays, 0.305, 0.511 ($\gamma^\pm$) daughter radiations from Gd^{147}	Pr^{141}(C^{12}, 6n) (TotK60)
Tb^{148}	70 m (TotK60) 66 m (BoncN61)	☢ EC, β^+ (TotK60) Δ −70.7 (MTW)	B chem, excit (TotK60)	β^+ 4.6 max γ Gd X-rays, 0.511 ($\gamma^\pm$), 0.78, 1.12	Pr^{141}(C^{12}, 5n) (TotK60)
Tb$^{[<157]}$	17 h (RolM53)	☢ β^- (RolM53)	G chem (RolM53) existence of a Tb isotope with A <162, $t_{1/2}$ ≈17 h, and Q_{β^-} >2 is highly improbable (LHP)	β^- 2.34 max	alphas on Eu (RolM53)
Tb$^{[<157]}$	>17 h (RolM53)	☢ β^+ (RolM53)	G chem (RolM53) probably a mixture of Tb^{152}, Tb^{155}, and Tb^{156} (LHP)	β^+ 3.1 max e^- 0.076, 0.088, 0.126, 0.153, 0.20	alphas on Eu (RolM53)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}≡0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{65}$Tb^{149}	4.10 h (TotK60a) 4.2 h (BruniE65) others (RasJ53, SurY57)	☢ EC 84%, α ≈16%, no β^+ (TotK60a, RasJ53, RolM53) Δ -71.4 (MTW)	A chem, mass spect (RasJ50, TotK60a) parent Eu^{145} (HoffR51) daughter Dy^{149} (TotK59) daughter Tb^{149m} (MacfR62) descendant Er^{153} (MacfR63a)	γ Gd X-rays, 0.16, 0.35 e^- 0.115, 0.127, 0.157, 0.301, 0.338, 0.587 α 3.95 daughter radiations from Gd^{149}	Pr^{141}(C^{12}, 4n) (TotK59) Eu^{151}(α, 6n) (RasJ53)
Tb^{149m}	4.3 m (MacfR62, MacfR64)	☢ [IT+EC+β^+] 99+%, α 0.025% (MacfR64)	B excit, cross bomb, genet (MacfR62) parent Tb^{149} (MacfR62)	γ [Tb X-rays] α 3.99 daughter radiations from Tb^{149}	La^{139}(O^{16}, 6n) (MacfR62, MacfR64)
Tb^{150}	3.1 h (TotK59d, TotK60a, BoncN61)	☢ EC, β^+ (TotK59d, TotK60, BoncN61) no α, lim 0.05% (TotK60a) Δ -71.03 (MTW)	A chem, mass spect (TotK59d, TotK60a)	β^+ 3.6 max γ Gd X-rays, 0.511 (↑ 100, $\gamma^{\pm}$), 0.637 (↑ 100), 0.93 (↑ 35)	protons on Gd (TotK59d, TotK60a)
Tb^{151}	18 h (TotK60a, BaranV58) 19 h (RasJ53) 20 h (MihJ57a) others (TotK58a, AntoN58)	☢ EC 99+%, α 0.0005% (MacfR64) Δ -71.6 (MTW)	A chem, excit (RasJ53, MihJ57a, TotK58a) chem, genet (BaranV58) chem, mass spect (TotK60a) parent Gd^{151} (BaranV58)	γ Gd X-rays, 0.108 (35%), 0.18 (18%, doublet), 0.252 (35%), 0.288 (32%), 0.40 (complex), 0.44 (complex), 0.48 (complex), 0.60 (complex), 0.72 (complex), 0.87 e^- 0.058, 0.100, 0.130, 0.202, 0.237 α 3.42	Eu^{151}(α, 4n) (TotK58a, MacfR64) protons on Gd (TotK60a, HarmB62)
Tb^{152}	17.4 h (TotK60a) 18.5 h (TotK59b) 19.6 h (StriA62) others (BoncN60, BoncN61, AbdurA60a)	☢ EC ≈80%, β^+ ≈20% (GromK65a) no α, lim 10^{-5}% (TotK59b) Δ -70.5 (MTW)	A chem, genet energy levels (TotK59b) chem, mass spect (TotK60a, StriA62) daughter Dy^{152} (BasiA60a)	β^+ 2.82 max e^- 0.221, 0.263, 0.294, 0.336, 0.382, 0.536, 0.565, 0.607 γ Gd X-rays, 0.271 (↑ 13), 0.344 (↑ 100), 0.411 (↑ 6), 0.586 (↑ 14), 0.779 (↑ 14), 0.974 (↑ 10), 1.12 (↑ 10, complex), 1.31 (↑ 11, complex), 1.60 (↑ 7, complex), 1.95 (↑ 8, complex), 2.40 (↑ 9, complex), 2.70 (↑ 6, complex)	Eu^{151}(α, 3n) (TotK59b) protons on Gd (TotK60a, StriA62)
Tb^{152}	4.0 m (OlkJ59a)	☢ EC, β^+, α 0.002% (OlkJ59a)	C excit, cross bomb, sep isotopes (OlkJ59a)	γ Tb X-rays, 0.14, 0.23, 0.511 ($\gamma^{\pm}$)	Eu^{151}(α, 3n), Gd^{152}(p, n) (OlkJ59a)
Tb^{153}	55 h (TotK60a) 63 h (StriA61) 62 h (MihJ57a) others (TotK59a, BaraV58, AntoN58)	☢ EC (MihJ57a) Δ -71 (MTW)	A chem, excit, genet (MihJ57a) chem, genet (BaraV58) chem, mass spect (TotK60a) parent Gd^{153} (MihJ57a, BaraV58) daughter Dy^{153} (DobA58)	γ Gd X-rays, 0.083 (11%, complex), 0.11 (12%, complex), 0.17 (9%, complex), 0.212 (30%), 0.250, 0.33, 0.88 e^- 0.012, 0.034, 0.037, 0.040, 0.044, 0.052, 0.057, 0.162 daughter radiations from Gd^{153}	protons on Gd (MihJ57a, HarmB62, TotK60a)
Tb^{154}	21.0 h (TotK60a) 17 h (WilkG50c, RolM53, HandT55b) others (MihJ57a, AntoN58, HenrR59, TotK59a)	☢ EC, β^+ ≈0.5% (?) (WilkG50c) Δ -70 (MTW)	A chem, excit (WilkG50c) chem, genet energy levels (MihJ57a) chem, excit, sep isotopes (HandT55b) chem, mass spect (TotK60a) not daughter Dy^{154} (MacfR61)	γ Gd X-rays, 0.123, 0.18?, 0.248, 0.30 (complex), 0.347, 0.53 (complex), 0.65 (complex), others to 2.5 e^- 0.073, 0.115, 0.122, 0.198	Eu^{151}(α, n) (WilkG50c) Eu^{153}(α, 3n) (TotK59a) protons on Gd (HandT55b, MihJ57a, TotK60a)
Tb^{154}	8.5 h (TotK60a) ≈7.5 h (HandT55b) 8 h (MihJ57a)	☢ EC, β^+ (?) (HandT55b) Δ -70 (MTW)	A chem, excit (HandT55a) chem, genet energy levels (MihJ57a) chem, mass spect (TotK60a) not daughter Dy^{154} (MacfR61)	γ Gd X-rays, 0.123, 0.18?, 0.248, 0.53 (complex), 0.65 (complex) e^- 0.073, 0.115, 0.122, 0.198	protons on Gd (HandT55b, MihJ57a, TotK60a)
Tb^{155}	5.6 d (MihJ57a) 5.4 d (TotK60a) 4.5 d (DzhB58) others (AntoN58)	☢ EC (MihJ57a, HarmB62) Δ -71 (MTW)	A chem, excit (WilkG50a) chem, sep isotopes, genet energy levels (MihJ57a) chem, mass spect (TotK60a) others (HandT55b) daughter Dy^{155} (GoroG57a, DobA58, MayM64)	γ Gd X-rays, 0.087 (37%), 0.105 (25%), 0.163 (8%, complex), 0.180 (8%), 0.262 (7%), 0.368 (4%) e^- 0.011, 0.034, 0.053, 0.078, 0.110, 0.129, 0.210	protons on Gd (MihJ57a, HandT55b, TotK60a)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{65}\mathrm{Tb}^{156}$	5.1 d (TotK60a) 5.3 d (HenrR59) 5.6 d (MihJ57a) others (HandT55b, WilkG50a, ButeF49, AntoN58, HolloJ59)	☢ EC, β^- (weak), no β^+ (HandT55b) no β^- (HolloJ59, OfeS59a) Δ −70 (MTW)	A chem, excit (HandT55b) chem, genet energy levels (MihJ57a)	γ Gd X-rays, 0.089 (17%), 0.199 (40%), 0.356 (13%), 0.535 (70%), 1.065 (12%), 1.16 (17%, complex), 1.22 (29%), 1.42 (15%), 1.65 (5%), 1.85 (4%) e^- 0.039, 0.081, 0.087, 0.149	$\mathrm{Eu}^{153}(\alpha,n)$ (HansP59, OfeS59a, WilkG50a) $\mathrm{Gd}^{156}(p,n)$ (WilkG50c)
Tb^{156m}	5.5 h (MihJ57, HandT55b) 5.0 h (WilkG50a)	☢ IT (MihJ57, MihJ57a) EC, β^+ <25% (WilkG50a) β^- (weak), no β^+ (HandT55b) Δ −70 (LHP, MTW)	B chem, excit (WilkG50a, HandT55b) chem, sep isotopes (MihJ57) chem, mass spect (TotK60)	γ [Tb L X-rays, Tb K X-rays (weak), 0.088 (weak)] e^- 0.036, 0.081 daughter radiations from Tb^{156}	$\mathrm{Gd}^{156}(p,n)$ (HandT55b, MihJ57)
Tb^{157}	1.5×10^2 y sp act (FujI64) 3×10^2 y sp act (GrigE64) others (IwaS63)	☢ EC (BhaM62, FujI64, IwaS63) Δ −70.71 (MTW)	A chem, mass spect (NauR60a, TotK60a) chem, sep isotopes, cross bomb (BhaM62) daughter Dy^{157} (IwaS63, FujI64)	γ Gd X-rays	$\mathrm{Dy}^{156}(n,\gamma)\mathrm{Dy}^{157}(\mathrm{EC})$ (NauR60a, BhaM62) $\mathrm{Gd}^{157}(p,n)$ (BhaM62) $\mathrm{Gd}^{156}(\alpha,3n)\mathrm{Dy}^{157}(\beta^-)$ (IwaS63, FujI64)
Tb^{158}	1.2×10^3 y (LewisH61) others (TotK60a, HandT55b, GovN58)	☢ EC 86%, β^- 14%, no β^+, lim 2% (BhaM62) Δ −69.43 (MTW)	A chem (ButeF60) chem, mass spect (NauR60a) chem, cross bomb, sep isotopes (BhaM62)	β^- 0.85 max e^- 0.029, 0.044, 0.072, 0.078, 0.092, 0.132 γ Gd X-rays, 0.080 (12%), 0.182 (10%), 0.782 (10%), 0.95 (69%, doublet), 1.110 (2.2%), 1.190 (1.8%)	$\mathrm{Dy}^{156}(n,\gamma)\mathrm{Dy}^{157}(\mathrm{EC})$ $\mathrm{Tb}^{157}(n,\gamma)$ (NauR60a, BhaM62, LewisH61, NauR62)
Tb^{158m}	10.5 s (SchmW65, GovN58) 11.0 s (HammC57) 10.2 s (BroaK65) others (HandT55b, PoolM38)	☢ IT (HandT55b) no β^- (lim 0.6%), no β^+ (lim 0.04%), no EC (lim 1.5%) (SchmW65) Δ −69.32 (LHP, MTW)	C excit (GovN58, HammC57)	e^- 0.060, 0.102 γ Tb X-rays, 0.110 (0.5%)	$\mathrm{Tb}^{159}(n,2n)$ (SchmW65) $\mathrm{Tb}^{159}(\gamma,n)$ (GovN58, HammC57)
Tb^{159}	$t_{1/2}$ (α) >5 × 10^{16} y sp act (PorsW54)	% 100 (HessD48, CollT57) Δ −69.53 (MTW) σ_c 46 (GoldmDT64)			
Tb^{160}	72.1 d (HoffD63) 72.3 d (KreK54) 73.0 d (ThirH57) others (BotW46a, BursS50, SmiRR56, IngM47c, KriN48, CorkJ50c, CorkJ48a)	☢ β^- (BotW43) no EC(K), lim 0.5% (ClarM57) Δ −67.85 (LHP, MTW) σ_c 525 (GoldmDT64)	A n-capt (BotW43) mass spect (IngM47c) chem (FolR51)	β^- 1.74 max (0.4%), 0.86 max e^- 0.033, 0.079, 0.085 γ Dy X-rays, 0.087 (12%), 0.197 (6%), 0.299 (30%), 0.879 (31%), 0.966 (31%, complex), 1.178 (15%), 1.272 (7%)	$\mathrm{Tb}^{159}(n,\gamma)$ (BotW43, BotW46a, SerL47b)
Tb^{161}	6.9 d (HoffD63, BisA56) 6.8 d (ButeF49, SmiRR56) 7.2 d (BaranS58, FunL64, HeiR50, CorkJ56a) others (CorkJ52c, BarlR55a)	☢ β^- (KriN48) Δ −67.47 (MTW)	A excit (KriN48) chem, excit (KetB49c) genet energy levels (CorkJ56a, SmiW56b) daughter Gd^{161} (KetB49c)	β^- 0.59 max (10%), 0.52 max e^- 0.017, 0.040, 0.048 γ Dy X-rays, 0.026 (21%), 0.049 (19%), 0.057 (5%), 0.075 (10%)	$\mathrm{Gd}^{160}(n,\gamma)\mathrm{Gd}^{161}(\beta^-)$ (KetB49b, KetB49c)
Tb^{162}	7.48 m (SchnT65)	☢ [β^-] (SchnT65) Δ −65 (MTW)	B genet energy levels, excit (SchnT65)	γ Dy X-rays, 0.040 (↑ 17), 0.081 (↑ 8), 0.140 (↑ 6), 0.180 (↑ 26), 0.258 (↑ 100), 0.81 (↑ 44), 0.89 (↑ 54) e^- [0.027, 0.072]	$\mathrm{Dy}^{162}(n,p)$ (SchnT65)
Tb^{162}	2.24 h (SchnT65) 2 h (FalK57)	☢ [β^-] (FalK57) Δ −65 (MTW)	C chem, excit, sep isotopes (FalK57)		$\mathrm{Gd}^{160}(\alpha,pn)$ (FalK57)
Tb^{163}	6.5 h (AlsJ60, TakaK62) others (FalK57)	☢ β^- (TakaK62) Δ −64.7 (MTW)	B chem, excit (fission yield) (AlsJ60) sep isotopes (TakaK62)	β^- 1.65 max γ Dy X-rays, 0.025, 0.235, 0.330, 0.510	$\mathrm{Gd}^{160}(\alpha,p)$ (FalK57) $\mathrm{Dy}^{164}(\gamma,p)$ (TakaK62) high energy fission (AlsJ60)
Tb^{163}	7 m (WilleR60)	☢ [β^-] (WilleR60)	E sep isotopes, excit (WilleR60) possibly identical to 7.5 m Tb^{162}	γ 0.18	$\mathrm{Dy}^{163}(n,p)$ (WilleR60)
$\mathrm{Tb}^{162,\,163}$	14 m (ButeF50)		F excit (ButeF50)		gammas on Dy (ButeF50)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M–A), MeV (C^{12} 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{65}$Tb^{164}	23 h (AlsJ60)	☢ [β^-] (AlsJ60) Δ −62 (MTW)	D chem, excit (fission yield) (AlsJ60)		high energy fission (AlsJ60)
$_{66}$Dy^{149}	10–20 m (TotK59, TotK58a)	☢ EC (TotK58a, TotK59)	C excit, genet (TotK59, TotK58a) parent Tb^{149} (TotK59)		Pr^{141}(N^{14}, 6n) (TotK59, TotK58a)
Dy^{150}	7.2 m (MacfR64) 8 m (TotK59) 7 m (RasJ53)	☢ EC, β^+, α (TotK59) EC+β^+ 82%, α 18% (MacfR64) Δ −69 (MTW)	C cross bomb (RasJ53) excit (TotK59) daughter Ho^{150} (MacfR63) daughter Er^{154} (MacfR63)	γ Tb X-rays, 0.39, 0.511 ($\gamma^{\pm}$) α 4.23 daughter radiations from Tb^{150}	Pr^{141}(N^{14}, 5n) (TotK59) Ce^{140}(O^{16}, 6n) (MacfR64) Tb^{159}(p, 10n) (RasJ53)
Dy^{151}	18.0 m (MacfR64) 19 m (TotK59, RasJ53)	☢ β^+ + EC 94%, α 6% (MacfR64) Δ −69 (MTW)	B cross bomb (RasJ53) excit (TotK59) daughter 35.6 s Ho^{151} (MacfR63)	α 4.06 γ Tb X-rays, 0.145, 0.511 ($\gamma^{\pm}$) daughter radiations from Tb^{151}	Pr^{141}(N^{14}, 4n) (TotK59) Ce^{140}(O^{16}, 5n) (MacfR64) Tb^{159}(p, 9n) (RasJ53)
Dy^{152}	2.41 h (SiiA62) 2.3 h (MacfR64, RasJ53, SurY57, BasiA60a) 2.5 h (TotK58a)	☢ EC, β^+ (?), α (RasJ53, TotK59) α 0.05% (MacfR64) Δ −70.11 (MTW)	A chem, excit (RasJ53, TotK58a) chem, genet (BasiA60a) parent 18 h Tb^{152} (BasiA60a) daughter 52.35 Ho^{152} (MacfR63)	γ Tb X-rays, 0.257, 0.511 ? ($\gamma^{\pm}$) α 3.65 daughter radiations from 18 h Tb^{152}	Pr^{141}(N^{14}, 3n) (TotK59) Gd^{152}(α, 4n) (TotK58a, MacfR64)
Dy^{153}	6.4 h (MacfR64) 5.5 h (RydH62) 5.0 h (TotK58a) 6.4 h (DzhB61a) others (DobA58, GoroG57a)	☢ EC, α 0.0030% (MacfR64) Δ −69.2 (MTW)	A chem, excit, sep isotopes (TotK58a) chem, mass spect, genet (DobA58) parent Tb^{153} (DobA58)	γ Tb X-rays, 0.08 (complex), [0.25 (complex)], others e^- 0.029, 0.047, 0.072, 0.091, 0.192, 0.202 α 3.48 daughter radiations from Tb^{153}	Gd^{152}(α, 3n) (TotK58a, MacfR64)
Dy^{154}	$t_{1/2}$ >10 y (MacfR61) $t_{1/2}$ (α) ≈1 x 10^6 y sp act (MacfR61)	☢ α (MacfR61) Δ −70.5 (MTW)	B chem, excit (MacfR61) not parent 21 h or 8.5 h Tb^{154} (MacfR61)	α 2.85	Gd^{154}(α, 4n) (MacfR61)
Dy^{154m}	13 h (TotK58a)	☢ α (TotK58a)	B chem, excit, sep isotopes (TotK58a)	α 3.37	Gd^{154}(α, 4n) (TotK58a)
Dy^{155}	10.2 h (PersL63c, PersL64a) others (MayM64, TotK58a, GoroG57a, BoncN60, DzhB58a, DobA58, MihJ57a)	☢ EC (TotK58a) β^+ 2% (PersL63c) Δ −69 (MTW)	A chem, excit (MihJ57a) chem, mass spect (DobA58) parent Tb^{155} (GoroG57a, DobA58, MayM64) daughter Ho^{155} (DalB60a, KalyA59, BasiA61)	γ Tb X-rays, 0.227 (68%), 0.52 (8%, complex), 0.65 (5%, complex), 0.74 (4%, complex), 0.91 (5%, complex), 1.000 (6%), 1.091 (5%), 1.16 (6%, complex), 1.250 (4%), 1.39 (3%), 1.45 (4%), 1.66 (2%) β^+ 1.08 max (0.14%), 0.85 max (2%) e^- 0.013, 0.038, 0.057, 0.175 daughter radiations from Tb^{155}	Tb^{159}(p, 5n) (MihJ57a, PersL64a) Gd^{153}(α, 2n), Gd^{154}(α, 3n) (TotK58a) Gd^{152}(α, n) (TotK61)
Dy^{156}	$t_{1/2}$ (α) >1 x 10^{18} y sp act (RieW58)	% 0.0524 (IngM48d) 0.057 (CollT57) Δ −70.9 (MTW) σ_c ≈3 (GoldmDT64)			
Dy^{157}	8.1 h (PersL63b) 8.2 h (MayM64, HandT53, RayG63) others (DobA58, GoroG57a)	☢ EC, no β^+ (HandT53) Δ −70 (MTW)	A chem, excit (HandT53) chem, sep isotopes (TotK61) chem, mass spect (DobA58) parent Tb^{157} (IwaS63, FujI64)	γ Tb X-rays, 0.326 (91%) e^- 0.009, 0.031, 0.052, 0.074, 0.274	Tb^{159}(p, 3n) (HandT53, PersL63b) Gd^{154}(α, n) (TotK61)
Dy^{158}		% 0.0902 (IngM48d) 0.100 (CollT57) Δ −70.37 (MTW) σ_c 100 (GoldmDT64)			
Dy^{159}	144 d (KetB59) 151 d (HoffD63) 138 d (RayG63, MayM64) others (ButeF51a, KetB49, BjoS61, GrigE60a)	☢ EC (KetB49) Δ −69.15 (MTW)	A chem, n-capt (KetB49) chem, cross bomb (ButeF51a) genet energy levels (MihJ57a)	γ Tb X-rays, 0.058 (4%), 0.348 (9 x 10^{-4}%) e^- 0.006, 0.049, 0.056	Dy^{158}(n, γ) (SerL47b, ButeF49, HeiR50) Tb^{159}(d, 2n) (ButeF51a) Tb^{159}(p, n) (KetB59)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{66}Dy^{160}$		% 2.294 (IngM48d) 2.35 (CollT57) Δ −69.67 (MTW)			
Dy^{161}		% 18.88 (IngM48d) Δ −68.05 (MTW) σ_c 600 (GoldmDT64)			
Dy^{162}		% 25.53 (IngM48d) 25.5 (CollT57) Δ −68.18 (MTW) σ_c 140 (GoldmDT64)			
Dy^{163}		% 24.97 (IngM48d) 24.9 (CollT57) Δ −66.36 (MTW) σ_c 130 (GoldmDT64)			
Dy^{164}		% 28.18 (IngM48d) 28.1 (CollT57) Δ −65.95 (MTW) σ_c 800 (to Dy^{165}) 2000 (to Dy^{165m}) (GoldmDT64)			
Dy^{165}	139.2 m (SherR52) 139.0 m (PersL63) others (BotW46a, KetB49, SerL47b, MangS62, SlaH46, MayE54)	☢ β^- (PoolM38a) Δ −63.51 (MTW) σ_c 4700 (GoldmDT64)	A n-capt (HevG36, MarsJK35) n-capt, sep isotopes (IngM47f) mass spect (IngM47a)	β^- 1.29 max e^- 0.039, 0.085 γ Ho X-rays, 0.095 (4%), 0.280 (0.6%), 0.361 (1.1%), 0.633 (0.7%), 0.716 (0.7%) others to 1.08	$Dy^{164}(n,\gamma)$ (MarsJK35, HevG36, PoolM38a, MeiL40, SerL47b, KetB49)
Dy^{165m_1}	1.26 m (HardR64) others (FlaA46, FlaA44a, HoleN48a)	☢ IT (FlaA44a) β^- 2.5% (HardR64) β^- 2.4% (TorR60) others (JorW53b) Δ −63.40 (LHP, MTW)	A n-capt (FlaA44a) n-capt, sep isotopes (IngM47f)	β^- 1.04 max (0.4%), 0.89 max e^- 0.054, 0.100, 0.106 γ Dy X-rays, 0.108 (3%), 0.152 (0.3%), 0.362 (0.6%), 0.514 (1.8%) daughter radiations from Dy^{165}	$Dy^{164}(n,\gamma)$ (FlaA44a, FlaA46, SerL47b, CaldR50, HardR64)
Dy^{165m_2}	32 s (HardR64)	☢ [IT] (HardR64)	C n-capt, sep isotopes (HardR64)	γ complex spectrum to 1.1	$Dy^{164}(n,\gamma)$ (HardR64)
Dy^{166}	81.5 h (HoffD63) 81.8 h (GunR62) others (HelmeR60, ButeF50a, KetB49)	☢ β^- (KetB49) Δ −62.59 (MTW)	A chem, genet (KetB49) parent Ho^{166} (KetB49, ButeF50a)	β^- 0.48 max (5%), 0.40 max e^- 0.019, 0.027, 0.046 γ Ho X-rays, 0.082 (12%), 0.372 (0.5%), 0.426 (0.5%) daughter radiations from Ho^{166}	$Dy^{164}(n,\gamma)Dy^{165}(n,\gamma)$ (KetB49, ButeF50a, RusL60, HelmeR60, GunR62, BrabV64, HoffD63)
Dy^{167}	4.4 m (WilleR60)	☢ [β^-] (WilleR60)	C sep isotopes, excit (WilleR60)		$Er^{170}(n,\alpha)$ (WilleR60)
$_{67}Ho^{150}$	≈20 s (MacfR63)	☢ [EC, β^+] (MacfR63)	F genet (MacfR63) parent Dy^{150} (MacfR63)		$Pr^{141}(O^{16}, 7n)$ (MacfR63)
Ho^{151}	35.6 s (MacfR63)	☢ β^+ + EC 80%, α 20% (MacfR63)	B excit, cross bomb, genet (MacfR63) parent Dy^{151} (MacfR63)	α 4.51 γ [Dy X-rays, 0.511 ($\gamma^{\pm}$)] daughter radiations from Dy^{151}, Tb^{147}	$Pr^{141}(O^{16}, 6n)$ (MacfR63)
Ho^{151}	42 s (MacfR63)	☢ α ≈30%, β^+ + EC ≈70% (MacfR64)	C excit, cross bomb (MacfR63)	α 4.60 γ [Dy X-rays, 0.511 ($\gamma^{\pm}$)] daughter radiations from Dy^{151}, Tb^{147}	O^{16} on Nd^{142} (MacfR63)
Ho^{152}	52.3 s (MacfR63)	☢ [EC+β^+] 81%, α 19% (MacfR63)	B excit, genet (MacfR63) parent Dy^{152} (MacfR63)	α 4.45	$Pr^{141}(O^{16}, 5n)$ (MacfR63)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}≡0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{67}$Ho^{152}	2.4 m (MacfR63) ≈4 m (RasJ53)	☢ [EC+β^+] ≈70%, α ≈30% (MacfR63) Δ −63.8 (MTW)	C excit (RasJ53) excit, cross bomb (MacfR63, MacfR64b) daughter Er^{152} (MacfR63a)	α 4.38	Pr^{141}(O^{16}, 5n) (MacfR63)
Ho^{153}	9 m (MacfR63)	☢ [EC+β^+], α 0.3% (MacfR63) Δ −65.0 (MTW)	C excit (MacfR63)	α 3.92	Pr^{141}(O^{16}, 4n) (MacfR63)
Ho^{153}	27 m (MayM64)	☢ [α] (MayM64)	F genet (MayM64) ancestor Eu^{145} (MayM64)		protons on Dy (MayM64)
Ho^{154}	7 m (LagP66)	☢ β^+, [EC] (LagP66) Δ −65 (MTW)	B chem, mass spect (LagP66)	γ [Dy X-rays], 0.335, 0.511 ($\gamma^{\pm}$)	protons on Dy (LagP66)
Ho^{155}	50 m (LagP66, KalyA59) 46 m (DalB60a)	☢ [EC], β^+ (KalyA59)	A chem, genet (KalyA59, DalB60a, BasiA61) mass spect (LagP66) parent Dy^{155} (DalB60a, KalyA59, BasiA61)	β^+ 2.1 max γ Dy X-rays, 0.092, 0.138, 0.511 ($\gamma^{\pm}$) daughter radiations from Dy^{155}	protons on Dy, Ho (LagP66)
Ho^{156}	55 m (LagP66, BasiA61) 57 m (GrigE60d) others (MihJ57a)	☢ [EC] (MihJ57a) β^+ (GrigE60d)	A chem, sep isotopes (MihJ57a) chem, mass spect (LagP66)	γ [Tb X-rays], 0.138 (↑ 100), 0.266 (↑ 99), 0.367 (↑ 23), 0.511 ($\gamma^{\pm}$), 0.685, 0.89, 1.20, 1.41 e^- 0.084, 0.130, 0.213 β^+ 2.9 max (↑ 1), 1.8 max (↑ 18)	Dy^{156}(p, n) (MihJ57a)
Ho^{157}	14 m (LagP66)	☢ β^+, [EC] (LagP66)	B [chem], mass spect (LagP66)	γ Dy X-rays, 0.087, 0.152, 0.190, 0.227, 0.511 ($\gamma^{\pm}$), 0.71, 0.86, 0.90, 1.20 daughter radiations from Dy^{157}	protons on Dy, Ho (LagP66)
Ho^{158}	11.5 m (SchepH62) 11 m (StenT65a)	☢ EC, no β^+, lim 10% (SchepH62) Δ −66.33 (MTW)	A chem (DneI60) chem, excit (SchepH62) chem, genet (StenT65a) daughter Ho^{158m} (StenT65a)	γ Dy X-rays, 0.099, 0.218, 0.329, 0.412, 0.52, 0.647, 0.73, 0.86, 0.940, 1.21, 1.47, 1.6, 1.8, 2.05, 2.21, 2.87, 3.1 e^- 0.045, 0.062, 0.091, 0.097, 0.164	Tb^{159}(α, 5n) (SchepH62)
Ho^{158m}	29 m (SchepH62) 27 m (DneI60, GromK61a) 22 m (LagP66) others (BasiA61, BoncN61a)	☢ IT (AbdurA61, GromK61a) [EC], β^+ (BoncN61a) Δ −66.26 (LHP, MTW)	A chem (DneI60) chem, excit (SchepH62) mass spect (LagP66) daughter Er^{158} (GromK61a, BoncN61a, AbdurA61) parent Ho^{158} (StenT65a)	γ Dy X-rays, Ho L X-rays, 0.099, 0.218, 0.32 (complex), 0.356 0.412, 0.46 (complex), 0.52, 0.63 (complex), 0.73 (complex), 0.85 (complex), 0.95 (complex), 1.21, 1.47, 1.60, 1.80, 2.06, 2.20, 2.62 e^- 0.029, 0.044, 0.072, 0.078, 0.092, 0.132 β^+ 1.32 max daughter radiations from Ho^{158} included in above listing	Tb^{159}(α, 5n) (SchepH62)
Ho^{159}	33 m (LagP66, TotK58) 35 m (MayM64)	☢ EC (TotK58) Δ −67 (MTW)	A chem, excit (TotK58) chem, sep isotopes (MayM64) daughter Er^{159} (AbdurA61a)	γ Dy X-rays, 0.057, 0.080, 0.13, 0.18 (complex?), 0.253, 0.309 e^- [0.026], 0.048, 0.071, 0.121, 0.198, 0.243, 0.256, 0.300	Tb^{159}(α, 4n) (TotK58) Dy^{160}(p, 2n) (MayM64)
Ho^{159m}	6.9 s (BorgJ66)	☢ IT (BorgJ66) Δ −67 (LHP, MTW)	A excit, sep isotopes, genet energy levels (BorgJ66)	γ Ho X-rays, 0.206 e^- 0.150, 0.197	daughter Er^{159} (AbdurA61a, LagP66) Dy^{160}(p, 2n) (BorgJ66)
Ho^{160}	25.6 m (StenT65, StenT65a) 28 m (TotK58, MayM64) 22.5 m (WilkG50a) ≈33 m (GoroG57a) ≈22 m (HandT54a)	☢ EC 99+%, β^+ ≈0.4% (GrigE59d) others (WilkG50a) Δ −66.4 (MTW)	A excit (WilkG50c) chem (HandT54a) chem, sep isotopes, excit (MayM64) daughter Ho^{160m} (GrigE62b) not daughter Er^{160}, lim 5% (DzhB63e)	see radiations of Ho^{160m}	daughter Ho^{160m} (GrigE62b) Tb^{159}(α, 3n) (WilkG50a, TotK58) protons on Dy (MayM64)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{67}$Ho^{160m}	5.0 h (StenT65, NerW55, MihJ57, HandT54a, RayG63) 4.8 h (GrigE60a) 4.6 h (WilkG50a) 5.3 h (DzhB57) others (DzhB57g)	☢ IT 66%, EC+β^+ 34% (NDS) β^+ ≈0.1% (GrigE59d) Δ −66.3 (LHP, MTW)	A chem, genet (NerW55) chem, sep isotopes (MihJ57) chem, excit, sep isotopes (MayM64) daughter Er^{160} (NerW55) parent Ho^{160} (GrigE62b)	γ Dy X-ray, 0.087 (14%), 0.197 (20%), 0.539 (5%), 0.646 (20%), 0.729 (50%), 0.880 (26%), 0.965 (37%, complex), others to 2.8 e^- 0.033, 0.051, 0.058, 0.079, 0.085, 0.144, 0.188 β^+ 1.9 max daughter radiations from Ho^{160} included in above listing	Tb^{159}(α, 3n) (TotK58, TotK59a, WilkG50a) daughter Er^{160} (BjoS61, RayG63, NerW55, GrigE62b) protons on Dy (MayM64)
Ho^{161}	2.4 h (DneI58) 2.5 h (RayG63, HandT54a, HandT54) others (BjoS61, BasiA61, WilkG50c)	☢ EC (HandT54a, HandT54) Δ −67 (MTW)	A chem, genet, excit (HandT54a, HandT54) daughter Er^{161} (HandT54, HandT54a)	γ Dy X-rays, 0.026 (23%), 0.075 (15%), 0.157 (1%), 0.176 (2%) e^- 0.017, 0.024, 0.049, 0.069, 0.076	Tb^{159}(α, 2n) (WilkG50a) protons on Dy (MayM64)
Ho^{161m}	6.1 s (BorgJ66) 6.8 s (StenT65a)	☢ IT (StenT65a, BorgJ66) Δ −67 (LHP, MTW)	A chem, genet (StenT65a, StenT65) excit, sep isotopes (BorgJ66) daughter Er^{161} (StenT65a, StenT65)	γ Ho X-rays, 0.211 (53%) e^- 0.155, 0.202	daughter Er^{161} (StenT65a, StenT65) Dy^{162}(p, 2n) (BorgJ66)
Ho^{162}	15 m (StenT65, StenT65a) 12 m (JorM61)	☢ EC 95%, β^+ 5% (JorM61) Δ −66.02 (MTW)	A genet (JorM61) chem, genet (StenT65, StenT65a) daughter Ho^{162m} (JorM61, StenT65, StenT65a)	γ Dy X-rays, 0.081 (8%), 0.511 (9%, $\gamma^\pm$) β^+ 1.10 max e^- 0.027, 0.072, 0.079	daughter Ho^{162m} (JorM61, HarmB61)
Ho^{162m}	68 m (JorM61, MayM64) 67 m (MihJ57a)	☢ IT 63%, EC 37% (JorM61) Δ −65.92 (LHP, MTW)	A chem, sep isotopes (MihJ57a) chem, mass spect (JorM61) others (HandT54a, WilkG50a) parent Ho^{162} (JorM61, StenT65, StenT65a)	γ Ho X-rays, Dy X-rays, 0.081 (10%), 0.185 (26%), 0.283 (12%), 0.940 (13%), 1.224 (24%) e^- 0.027, 0.036, 0.048, 0.072, 0.079, 0.131, 0.177 daughter radiations from Ho^{162}	Tb^{159}(α, n) (JorM61) protons on Dy (MayM64)
Ho^{163}	$t_{1/2}$ >10^3 y sp act (NauR60) others (BjoS61)	Δ −66.35 (MTW)	A chem, mass spect (NauR60)		Er^{162}(n, γ)Er^{163}(EC) (NauR60)
Ho^{163m}	1.1 s (BorgJ66) 0.8 s (HammC57)	☢ IT (GovN58) Δ −66.05 (LHP, MTW)	B excit (GovN58) excit, sep isotopes (BorgJ66)	γ Ho X-rays, 0.305 e^- 0.249, 0.296	Ho^{165}(γ, 2n) (HammC57, GovN58)
Ho^{164}	36.7 m (BrowHN54) 34.0 m (WilkG50a) 41.5 m (WafH50) 47 m (PoolM38a) others (HandT54a)	☢ β^- 53%, EC 47%, no β^+, lim 0.05% (BrowHN54) Δ −64.84 (MTW)	A excit (PoolM38a)	β^- 0.99 max e^- 0.019, 0.034, 0.065, 0.071, 0.083, 0.089 γ Dy, Er X-rays, 0.073, 0.091	protons on Dy (WilkG50a, MihJ57a) Ho^{165}(γ, n) (WafH48, BrowHN54) Ho^{165}(n, 2n) (PoolM38a, WafH50)
Ho^{165}	$t_{1/2}$ (α) >6 x 10^{16} y sp act (PorsW54)	% 100 (LeiW50, CollT57) Δ −64.81 (MTW) σ_c 64 (to Ho^{166}) ≈1 (to Ho^{166m}) (GoldmDT64)			
Ho^{166}	26.9 h (GranP49, CorkJ58) 27.0 h (HoffD63) others (FunL63, IngM47, BotW46a, AntoN50, AntoN50a, KetB49b, CorkJ49b)	☢ β^- (HevG36) Δ −63.07 (MTW)	A n-capt (HevG36) mass spect (IngM47) chem (KetB49b) daughter Dy^{166} (KetB49, ButeF50a)	β^- 1.84 max e^- 0.023, 0.072, 0.078 γ Er X-rays, 0.081 (5.4%), 1.380 (0.9%), 1.582 (0.20%), 1.663 (0.10%)	Ho^{165}(n, γ) (HevG36, PoolM38a, MeiL40, SerL47b) daughter Dy^{166} (KetB49, ButeF50a, HoffD63)
Ho^{166m}	1.2 x 10^3 y sp act, mass spect (FalK65) others (ButeF52)	☢ β^- (ButeF52) Δ −63.06 (LHP, MTW)	A chem, excit (ButeF52) chem, genet energy levels (MiltJ55)	β^- [0.07 max] e^- 0.023, 0.072, 0.078, 0.127, 0.175 γ Er X-rays, 0.081 (12%), 0.184 (90%), 0.280 (30%), 0.412 (12%), 0.532 (12%), 0.711 (58%), 0.810 (60%), 0.830 (11%), others to 1.43	Ho^{165}(n, γ) (ButeF52)
Ho^{167}	3.1 h (WilleR60) 3.0 h (HandT55)	☢ β^- (HandT55) Δ −62.3 (MTW)	A chem, excit (HandT55) genet energy levels (HarmB62)	β^- 0.96 max e^- 0.024, 0.048, 0.073, 0.150, 0.180, 0.199, 0.263 γ Er X-rays, [0.079, 0.083, 0.208, 0.238, 0.321, 0.348, 0.387]	Er^{170}(p, α) (HandT55) Er^{167}(n, p) (WilleR60, HandT55)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{67}$Ho^{168}	3.3 m (WilleR60) 3.5 m (TakaK61)	☢ β^- TakaK61) Δ −59.7 (MTW)	C sep isotopes, cross bomb (WilleR60)	β^- 2.2 max γ 0.85	Er^{168}(n, p) (WilleR60, TakaK61)
Ho^{169}	4.8 m (MiyK63)	☢ β^- (MiyK63) Δ −58.8 (MTW)	C excit, sep isotopes, decay charac (MiyK63)	β^- 1.95 max γ 0.15, 0.68, 0.76, 0.84, 0.92	Er^{170}(γ, p) (MiyK63)
Ho^{169}	96 m (ButeF50)	☢ (ButeF50)	G excit (ButeF50) possibly Er^{163} (LHP)		gammas on Er (ButeF50)
Ho^{170}	45 s (TakaK61) 40 s (WilleR60)	☢ β^- (TakaK61) Δ −55.8 (MTW)	C excit, sep isotopes (WilleR60)	β^- 3.1 max γ 0.43	Er^{170}(n, p) (WilleR60, TakaK61)
$_{68}$Er^{152}	10.7 s (MacfR63a)	☢ α ≈90%, [EC+β^+] ≈10% (MacfR63a)	C excit, cross bomb (MacfR63a, MacfR64b) parent 2.4 m Ho^{152} (MacfR63a)	α 4.80	Pr^{141}(F^{19}, 8n), Nd^{142}(O^{16}, 6n), Ce^{140}(Ne^{20}, 8n) (MacfR64b, MacfR63a)
Er^{153}	36 s (MacfR63a)	☢ α >75%, EC+β^+ <25% (MacfR63a)	B excit, cross bomb, genet (MacfR63a, MacfR64b) ancestor Tb^{149} (MacfR63a)	α 4.67	Nd^{142}(O^{16}, 5n) (MacfR63a) Pr^{141}(F^{19}, 7n), Ce^{140}(Ne^{20}, 7n) (MacfR64b)
Er^{154}	5 m (MacfR63a)	☢ α (MacfR63a) Δ −63 (MTW)	C excit, genet (MacfR63a) parent Dy^{150} (MacfR63a)	α 4.15 daughter radiations from Dy^{150}	Nd^{142}(O^{16}, 4n) (MacfR63a)
Er^{157}	≈25 m (LagP66)	☢ β^+, [EC] (LagP66)	B [chem], mass spect (LagP66)	γ Ho X-rays, 0.117, 0.386, 0.511 ($\gamma^{\pm}$), 1.32, 1.66, 1.82, 2.0 daughter radiations from Ho^{157}	Ho^{165}(p, 9n) (LagP66)
Er^{158}	2.3 h (StenT65, GromK61a) 2.4 h (DneI60) 2.5 h (BoncN61a)	☢ EC, β^+ (BoncN61a)	B chem, genet (GromK61a, BoncN61a) parent Ho^{158m} (GromK61a, BoncN61a, AbdurA61)	γ Ho X-rays, 0.072, 0.250, 0.315, 0.387, 0.511 ($\gamma^{\pm}$), 0.875, 0.906 0.978 e^- 0.058, 0.065 β^+ 0.8 max daughter radiations from Ho^{158m}, Ho^{158}	protons on Ta (GromK61a, AbdurA61, BoncN61a, DneI60) Ho^{165}(p, 8n) (LagP66)
Er^{159}	36 m (LagP66) 1 h (AbdurA61a)	☢ [EC, β^+] (AbdurA61a)	A chem, atomic level spacing, genet (AbdurA61a) mass spect (LagP66) parent Ho^{159} (AbdurA61a)	γ Ho X-rays, 0.206, 0.37, 0.511 ($\gamma^{\pm}$), 0.62 (complex), 0.84, 1.20, 1.40, 1.80, 2.60 e^- 0.150, 0.197 daughter radiations from Ho^{159} daughter radiations from Ho^{159m} included in above listing	Ho^{165}(p, 7n) (LagP66) protons on Ta (AbdurA61a)
Er^{160}	29.4 h (NerW55) 28.7 h (BjoS61) 29.5 h (RayG63) others (MicM54, DzhB57, GoroG57a, LagP66)	☢ [EC], no β^+ (NerW55)	A chem, mass spect (NerW55, MicM54) parent Ho^{160m} (NerW55) not parent Ho^{160}, lim 5% (DzhB63e)	γ Ho X-rays daughter radiations from Ho^{160m} and Ho^{160}	protons on Er (RayG63, BjoS61)
Er^{161}	3.1 h (NerW55, RayG63, GrenH61) 3.2 h (BjoS61, GromK61a, DneI60a) others (HandT54, MicM54)	☢ [EC], β^+ (NerW55) EC, no β^+, lim 3% (HandT54, GrenH61) Δ −65 (MTW)	A chem, cross bomb, excit (HandT54) chem, mass spect (MicM54, NerW55) parent Ho^{161} (HandT54, HandT54a) daughter Tm^{161} (ButeF60, RayG63) parent Ho^{161m} (StenT65a, StenT65)	γ Ho X-rays, 0.211 (9%), 0.305 (3%), 0.592 (8%), 0.826 (63%), 1.17 (8%, complex), 1.37 (5%, complex), 1.66 (2%, complex) e^- 0.059, 0.065, 0.155, 0.202 β^+ 1.2 max daughter radiations from Ho^{161} daughter radiations from Ho^{161m} included in above listing	protons on Er (RayG63, HarmB59, BjoS61, ButeF60)
Er^{162}		% 0.136 (HaydR50) Δ −66.4 (MTW) σ_c 2 (GoldmDT64)			
Er^{163}	75.1 m (PersL63d) others (HandT53a, BjoS61, StenT65)	☢ EC 99+%, β^+ 0.004% (PersL63d) Δ −65.14 (MTW)	A chem, excit (HandT53a, PersL63d) chem, genet (ButeF60, BjoS61) daughter Tm^{163} (ButeF60, BjoS61)	γ Ho X-rays, 0.43 (0.06%), 1.10 (0.04%) β^+ 0.19 max	Ho^{165}(p, 3n) (HandT53a, PersL63d)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (△≡M−A), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{68}$Er^{164}		% 1.56 (HaydR50) Δ −65.87 (MTW) σ_c 1.7 (GoldmDT64)			
Er^{165}	10.34 h (RydH63) 10.3 h (StenT65) 10.4 h (ZylJ63) others (RayG63, BjoS61, SchoR63, ButeF50b, GrigO58, GoroG57)	☢ EC (ButeF50b) Δ −64.44 (MTW)	A chem, excit (ButeF50b) chem, mass spect (NierW56, BjoS61) daughter Tm^{165} (HandT53a, NerW54)	γ Ho X-rays, continuous bremsstrahlung to 0.37	Ho^{165}(d, 2n) (RydH63) Ho^{165}(p, n) (RayG63) Er^{164}(n, γ) (SchoR63)
Er^{166}		% 33.41 (HaydR50) Δ −64.92 (MTW) σ_c 12 (GoldmDT64)			
Er^{167}		% 22.94 (HaydR50) Δ −63.29 (MTW) σ_c 700 (GoldmDT64)			
Er^{167m}	2.3 s (AlexKF63) 2.5 s (DMatE49, HammC57)	☢ IT (DMatE49) Δ −63.08 (LHP, MTW)	B n-capt (DMatE49) excit (HammC57) genet (MihJ57a) daughter Tm^{167} (MihJ57a)	γ Er X-rays, 0.208 (43%) e$^-$ 0.150, 0.199	daughter Tm^{167} (MihJ57, MihJ57a) daughter Ho^{167} (HarmB62) Er^{166}(n, γ) (DMatE49, AlexKF63)
Er^{168}		% 27.07 (HaydR50) Δ −62.98 (MTW) σ_c 2 (GoldmDT64)			
Er^{169}	9.6 d (BjoS61) 9.0 d (RayG63) 9.4 d (KetB48) 9.0 d (BisA56c, ButeF50) others (WilleR60)	☢ β$^-$ (KetB48) Δ −60.91 (MTW)	A chem, n-capt (KetB48) genet energy levels (HatE56a) chem, mass spect (BjoS61)	β$^-$ 0.34 max e$^-$ 0.006 γ [Tm M X-rays], 0.008 (0.3%)	Er^{168}(n, γ) (KetB48)
Er^{170}		% 14.88 (HaydR50) Δ −60.0 (MTW) σ_c 9 (GoldmDT64)			
Er^{171}	7.52 h (CranF58) others (KellH51, KetB48)	☢ β$^-$ (KetB48) Δ −57.6 (MTW)	A n-capt (HevG36, NeunE35) chem, genet (KetB48) chem, mass spect (NetD56) parent Tm^{171} (KetB48)	β$^-$ 1.49 max (2.3%), 1.06 max e$^-$ 0.004, 0.052, 0.065, 0.102, 0.115 γ Tm X-rays, 0.112 (25%), 0.124 (9%), 0.296 (28%), 0.308 (63%), others to 0.96	Er^{170}(n, γ) (HevG36, PoolM38a, KetB48, BotW46a, NeunE35)
Er^{172}	49.5 h (HansP61a) 48.7 h (GunR62) others (NetD56, OrtC61)	☢ β$^-$ (OrtC61) Δ −56.5 (MTW)	A chem, genet (NetD56) parent Tm^{172} (NetD56)	β$^-$ 0.89 max (<10%), 0.37 max e$^-$ 0.010, 0.020, 0.049, 0.058, 0.348 γ Tm X-rays, 0.407 (40%), 0.610 (40%) daughter radiations from Tm^{172}	Er^{170}(n, γ) Er^{171}(n, γ) (NetD56, OrtC61, HelmeR61b, HansP61a, GunR62)
Er^{173} (or Tm^{176}, Yb^{172})	2.0 m (WilleR60)	☢ β$^-$ or IT (WilleR60)	F sep isotopes (WilleR60)	γ 0.18, 0.25, 0.36	neutrons on Yb^{176} (WilleR60)
$_{69}$Tm^{153}	1.6 s (MacfR64b)	☢ α (MacfR64b)	C excit, cross bomb (MacfR64b)	α 5.10	Pr^{141}(Ne^{20}, 8n), Nd^{142}(F^{19}, 8n) (MacfR64b)
Tm^{154}	3.0 s (MacfR64b)	☢ α (MacfR64b)	C excit, cross bomb (MacfR64b)	α 5.04	Pr^{141}(Ne^{20}, 7n), Nd^{142}(F^{19}, 7n) (MacfR64b)
Tm^{154}	5 s (MacfR64b)	☢ α (MacfR64b)	E excit, cross bomb (MacfR64b)	α 4.96	Pr^{141}(Ne^{20}, 7n), Nd^{142}(F^{19}, 7n) (MacfR64b)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C¹²=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{69}$Tm^{161}	32 m (ButeF60) 30 m (HarmB59) 20 to 30 m (RayG63) 44 m (GromK63)	☢ EC (HarmB59) Δ −62 (MTW)	A chem, sep isotopes (HarmB59) chem, genet (ButeF60) chem, excit, sep isotopes, genet (RayG63) parent Er^{161} (ButeF60, RayG63)	γ Er X-rays, 0.084, 0.106, 0.112, 0.145 (complex), 0.172, others e^- 0.027, 0.036, 0.050, 0.055, 0.065, 0.075, 0.089, 0.115, others daughter radiations from Er^{161}	Er^{162}(p, 2n) (RayG63, HarmB59)
Tm^{162}	77 m (WilsRG60g) 90 m (RayG63) activity not observed, $t_{1/2}$ <45 m (BjoS61)	☢ EC (WilsRG60g) Δ −61.5 (MTW)	B excit, sep isotopes (WilsRG60g) chem, excit, sep isotopes (RayG63)	γ Er X-rays, 0.102 (↑ 20), 0.236 (↑ 10)	protons on Er (RayG63, WilsRG60g)
Tm^{162}	22 m (AbdumA63)	☢ β^+, EC (AbdumA63) Δ −61.5 (MTW)	D chem (AbdumA63) daughter Yb^{162} (AbdumA63)	β^+ 3.82 max e^- 0.045, 0.093, 0.100 γ [Er X-rays, 0.102, 0.511 ($\gamma^{\pm}$)]	daughter Yb^{162} (AbdumA63)
Tm^{163}	1.8 h (BjoS61, GromK63, RayG63) others (HarmB59, BoncN60, ButeF60)	☢ EC (HarmB59) β^+ (BoncN60) Δ −62.87 (MTW)	A chem, sep isotopes (HarmB59) chem, mass spect (BjoS61) chem, sep isotopes, excit (RayG63) parent Er^{163} (ButeF60, BjoS61)	γ Er X-rays, 0.104 (↑ 8), 0.17 (↑ 1, complex), 0.240 (↑ 5, complex), 0.29 (↑ 3, complex), 0.34 (↑ 3, complex) e^- 0.047, 0.095, 0.184 β^+ 1.1 max daughter radiations from Er^{163}	Er^{164}(p, 2n) (RayG63)
Tm^{164}	2.0 m (WilsRG60g) 1.8 m (RayG63)	☢ EC 50%, β^+ 50% (WilsRG60g) Δ −61.91 (MTW)	A chem, genet energy levels (DalB60, AbdurA60, AbdurA60b) excit, sep isotopes (RayG63, WilsRG60g) daughter Yb^{164} (DalB60, AbdurA60, AbdurA60b)	γ Er X-rays, 0.091 (4%), 0.356, 0.361, 0.391, 0.511 (100%, $\gamma^{\pm}$), 0.773, 0.862, 0.907, 0.930 β^+ 2.94 max e^- 0.034, 0.083, 0.089	Er^{164}(p, n) (RayG63, WilsRG60g)
Tm^{165}	30.1 h (BjoS61) others (MicM54, RayG63, GoroG57, HandT53a)	☢ EC, no β^+ (HandT53a) β^+ 0.007% (PreiZ65) Δ −62.87 (PreiZ65, MTW)	A chem, excit (HandT53a) chem, mass spect (MicM54) parent Er^{165} (HandT53a, NerW54)	γ Er X-rays, 0.054, 0.113, 0.243 (↑ 50), 0.297 (↑ 35, complex), 0.34 (↑ 10, complex), 0.44 (↑ 5, complex), 0.70 (↑ 2), 0.807 (↑ 15), 1.13 (↑ 5), 1.30 (↑ 1) e^- 0.038, 0.045, 0.052, 0.056, 0.068, 0.161, 0.185, 0.233, 0.240 β^+ 0.30 max daughter radiations from Er^{165}	protons on Er (RayG63)
Tm^{166}	7.7 h (WilsRG60d, GrigE60a, WilkG49b, RayG63, MicM54) others (BjoS61, BoncN60, PariP63)	☢ EC 98.2%, β^+ 2% (GrigE61) others (WilsRG60d, WilkG49b) Δ −61.88 (LHP, MTW)	A chem, excit (WilkG49a) chem, mass spect (MicM54) daughter Yb^{166} (FolR51, NerW55, GoroG57)	β^+ 1.94 max e^- 0.023, 0.072, 0.079, 0.127 γ Er X-rays, 0.081, 0.19 (doublet), 0.215, 0.46, 0.60 (complex), 0.69 (complex), 0.78 (complex), 1.180, 1.277, 1.378, 1.873, 2.06 (doublet)	Ho^{165}(α, 3n) (WilkG49b) protons on Yb (WilkG49b, RayG63, WilsRG60d)
Tm^{167}	9.6 d (NaraH60, WilkG49b, NerW55, RayG63) 9.3 d (BjoS61, BonnN62)	☢ EC, no β^+ (WilkG49b) no β^+, lim 0.3% (GromK62) Δ −62.13 (GromK62, MTW)	A chem, excit (WilkG49a, RayG63) chem, mass spect (MicM54, NerW55, BjoS61) parent Er^{167m} (MihJ57a) daughter Yb^{167} (WilsRG60f)	γ Er X-rays, 0.057 (4%), 0.208 (43%), 0.532 (2%) e^- 0.048, 0.150, 0.199 daughter radiations from Er^{167m} included in above listing	Ho^{165}(α, 2n) (RayG63) protons on Er (RayG63)
Tm^{168}	85 d (WilkG49b) 86 d (RayG63) 87 d (HandT54b) 93 d (BonnN62) others (BjoS61, GoroG57)	☢ EC, β^- (?) ≈2% (WilkG49b) Δ −61.27 (MTW)	A chem, excit (WilkG49b, RayG63) chem, mass spect (BjoS61)	γ Er X-rays, 0.080 (11%), 0.19 (77%, complex), 0.448 (27%), 0.63 (14%, complex), 0.73 (40%, complex), 0.82 (88%, complex), 0.917 (4%), 1.280 (3%) e^- 0.022, 0.071, 0.077, 0.127, 0.141	Er^{170}(p, 3n) (RayG63) Ho^{165}(α, n) (WilkG49b) Er^{168}(p, n) (RayG63)
Tm^{169}	$t_{1/2}$ (α) >5 x 10^{16} y sp act (PorsW54)	% 100 (LagC50, CollT57) Δ −61.25 (MTW) σ_c 125 (GoldmDT64)			
Tm^{170}	134 d (FlyK65a) 125 d (BonnN62) others (BotW46, CaldR50, KetB49b)	☢ β^- (BotW46) EC(K) 0.15% (DayP56) no EC(K), lim 0.3%, no β^+, lim 0.01% (GrahR52) Δ −59.6 (MTW) σ_c 150 (GoldmDT64)	A n-capt (NeunE36) chem (KetB48a)	β^- 0.97 max e^- 0.023, 0.075, 0.082 γ Yb X-rays, 0.084 (3.3%)	Tm^{169}(n, γ) (HevG36, NeunE36, SerL47b) Er^{170}(p, n) (RayG63)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
${}_{69}Tm^{171}$	1.92 y (FlyK65a) 1.9 y (KetB49b)	☢ β^- (KetB48) Δ −59.1 (MTW)	A chem, genet (KetB48) chem, mass spect (NetD56) daughter Er^{171} (KetB48)	β^- 0.097 max e^- 0.057, 0.065 γ Yb X-rays, 0.067	$Er^{170}(n,\gamma)Er^{171}(\beta^-)$ (KetB48)
Tm^{172}	63.6 h (NetD56) 63.5 h (HansP61a) others (KuroT61b, FolR51)	☢ β^- (FolR51) Δ −57.4 (MTW)	A chem (FolR51) chem, n-capt, mass spect (NetD56) daughter Er^{172} (NetD56)	β^- 1.88 max γ Yb X-rays, 0.079 (5%), 0.181 (2.2%), 0.91 (1.4%), 1.09 (7%), 1.39 (7%), 1.46 (7%), 1.53 (6%), 1.61 (5%)	daughter Er^{172} (NetD56, HelmeR61a, HansP61a, OrtC61)
Tm^{173}	8.2 h (OrtC63, KuroT63) others (KuroT61b)	☢ β^- (KuroT61b) Δ −56.4 (MTW)	B chem, sep isotopes, cross bomb (OrtC63)	β^- 1.3 max (2%), 0.89 max e^- 0.008, 0.056, 0.064 γ Yb X-rays, 0.066 (1.1%), 0.399 (89%), 0.465 (8%)	$Er^{170}(\alpha,p)$ (OrtC63) $Yb^{173}(n,p)$ (OrtC63) $Yb^{174}(\gamma,p)$ (KuroT63, OrtC63, KuroT61b)
Tm^{174}	5.5 m (WilleR60) 5 m (TakaK61)	☢ β^- (TakaK61) Δ −54.6 (TakaK61, MTW)	E sep isotopes (WilleR60) decay charac (TakaK61)	β^- 2.5 max γ no γ	$Yb^{174}(n,p)$ (WilleR60, TakaK61)
Tm^{174}	5.2 m (KantJ64c)	☢ β^- (KantJ64c) Δ −54.1 (MTW)	B genet energy levels (KantJ64c, OrtC64)	β^- 1.2 max e^- 0.015, 0.067, 0.074 γ Yb X-rays, 0.176 (67%), 0.273 (85%), 0.366 (93%), 0.50 (15%), 0.99 (89%)	$Yb^{174}(n,p)$ (KantJ64b)
Tm^{175}	20 m (KuroT61b) 19 m (ButeF50)	☢ β^- (KuroT61b) Δ −52.3 (LHF, MTW)	E excit (ButeF50) excit, decay charac (KuroT61b)	β^- 2.0 max γ 0.51	$Yb^{176}(\gamma,p)$ (KuroT61b)
Tm^{176}	1.5 m (TakaK61)	☢ β^- (TakaK61) Δ −49.2 (MTW)	F decay charac (TakaK61)	β^- 4.2 max γ no γ	$Yb^{176}(n,p)$ (TakaK61)
Tm^{176} (or Er^{175}, Yb^{177})	2.0 m (WilleR60)	☢ IT or β^- (WilleR60)	F sep isotopes (WilleR60)	γ 0.18, 0.25, 0.36	neutrons on Yb^{176} (WilleR60)
${}_{70}Yb^{154}$	0.39 s (MacfR64b)	☢ α (MacfR64b)	C excit, cross bomb (MacfR64b)	α 5.33	$Sm^{144}(O^{16},6n)$, $Nd^{142}(Ne^{20},8n)$ (MacfR64b)
Yb^{155}	1.6 s (MacfR64b)	☢ α (MacfR64b)	C excit, cross bomb (MacfR64b)	α 5.21	$Sm^{144}(O^{16},5n)$, $Nd^{142}(Ne^{20},7n)$ (MacfR64b)
Yb^{162}	≈24 m (AbdumA63)	☢ [EC] (AbdumA63)	D chem (AbdumA63) parent 22 m Tm^{162} (AbdumA63)	γ [Tm X-rays] e^- 0.032, 0.039 daughter radiations from 22 m Tm^{162}	protons on Ta (AbdumA63)
Yb^{164}	75 m (DalB60, AbdurA60b, AbdurA60) 78 m (PariP64) 74 m (ButeF60) others (NerW55, KalyA59)	☢ EC (DalB60, AbdurA60, AbdurA60b)	A chem (NerW55) chem, genet (AbdurA60, DalB60, AbdurA60b) chem, mass spect (PariP64) parent Tm^{164} (AbdurA60b, DalB60, AbdurA60)	γ Tm X-rays daughter radiations from Tm^{164}	$Tm^{169}(p,6n)$ (ButeF60, PariP64)
Yb^{165}	10.5 m (PariP64)	☢ [EC, β^+] (PariP64) Δ −60 (MTW)	C mass spect (PariP64)		$Tm^{169}(p,5n)$ (PariP64)
Yb^{166}	57.5 h (PariP63) 54 h (NerW55) 62 h (FolR51) 60 h (GoroG57)	☢ EC (FolR51) Δ −61.6 (MTW)	A chem, genet (FolR51) chem, mass spect (MicM54, NerW55) parent Tm^{166} (FolR51, NerW55, GoroG57)	γ Tm X-rays, 0.082 (17%) e^- 0.023, 0.072 daughter radiations from Tm^{166}	$Tm^{169}(p,4n)$ (PariP63)
Yb^{167}	17.7 m (WilsRG60f) 17.3 m (WanC64) others (HandT54b, BasiA60b)	☢ EC, no β^+ (HandT54b) β^+ 0.4% (WanC64) β^+ 0.2% (TamT65) Δ −60.17 (MTW, GromK62)	B chem, excit (HandT54b) genet (WilsRG60f) parent Tm^{167} (WilsRG60f) daughter Lu^{167} (AroP58, ButeF60)	γ Tm X-rays, 0.113 (90%, complex), 0.176 (15%) e^- 0.047, 0.055, 0.096	daughter Lu^{167} (HarmB59) $Tm^{169}(p,3n)$ (HandT54b) $Er^{164}(\alpha,n)$ (WilsRG60f)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{70}Yb^{168}$		% 0.140 (BaiK50) 0.135 (CollT57) Δ -61.3 (MTW) σ_c 11, 000 (GoldmDT64)			
Yb^{169}	31.8 d (WalkD49a) 30.6 d (CorkJ56) 33 d (BotW46, MartiDS51, HandT54b)	☢ EC (BotW46) Δ -60 (MTW)	A n-capt (BotW46) chem, excit (KetB48a) mass spect (MicM54) daughter Lu^{169} (GoroG57b, MerE61)	γ Tm L X-rays (56%), Tm K X-rays (185%), 0.063 (45%), 0.110 (18%), 0.131 (11%), 0.177 (22%), 0.198 (35%), 0.308 (10%) e^- 0.004-0.011, 0.034, 0.050, 0.053, 0.071, 0.100, 0.118, 0.121, 0.139	$Yb^{168}(n, \gamma)$ (AttH45, BotW46) $Tm^{169}(d, 2n)$ (KetB48a)
Yb^{169m}	46 s (HoffK60a) 50 s (DMatE49)	☢ IT (DMatE49) Δ -60 (LHP, MTW)	B n-capt (DMatE49) n-capt, sep isotopes (HoffK60a) daughter Lu^{169} (HarmB60)	γ Yb L X-rays e^- 0.014, 0.022	$Yb^{168}(n, \gamma)$ (DMatE49, HoffK60a)
Yb^{170}		% 3.03 (BaiK50) 3.14 (CollT57) Δ -60.5 (MTW)			
Yb^{171}		% 14.31 (BaiK50) 14.4 (CollT57) Δ -59.2 (MTW)			
Yb^{171m}	<<8 d (MihJ57)	☢ IT (MihJ57a, MihJ57) Δ -59.1 (LHP, MTW)	D chem (MihJ57) daughter Lu^{171} (MihJ57a, MihJ57, HarmB60)	γ Yb L X-rays, 0.019, 0.076 e^- 0.010, 0.017, 0.067, 0.074	daughter Lu^{171} (MihJ57, MihJ57a)
Yb^{172}		% 21.82 (BaiK50) 21.9 (CollT57) Δ -59.3 (MTW)			
Yb^{173}		% 16.13 (BaiK50) 16.2 (CollT57) Δ -57.7 (MTW)			
Yb^{174}		% 31.84 (BaiK50) 31.6 (CollT57) Δ -57.1 (MTW) σ_c 9 (to Yb^{175}) 46 (to 0.513 level of Yb^{175}) (GoldmDT64)			
Yb^{175}	101 h (AttH45, (CorkJ56) 102 h (IngM47a) 99 h (BotW46)	☢ β^- (AttH45) Δ -54.8 (MTW)	A n-capt (BotW46, AttH45) mass spect (IngM47a) chem (KetB49b)	β^- 0.466 max γ Lu X-rays, 0.114 (1.9%), 0.283 (3.7%), 0.396 (6.0%) e^- 0.051, 0.102, 0.112, 0.333	$Yb^{174}(n, \gamma)$ (AttH45, BotW46, IngM47a)
Yb^{176}		% 12.73 (BaiK50) 12.6 (CollT57) Δ -53.4 (MTW) σ_c 7 (GoldmDT64)			
Yb^{176m}	11.7 s (KantJ62) 11 s (VergM65)	☢ [IT] (KantJ62) Δ -52.4 (LHP, MTW)	B sep isotopes, excit (KantJ62) genet energy levels (DBoeJ64, KantJ62)	γ Yb X-rays, 0.19, 0.29, 0.39	$Yb^{176}(n, n')$ (KantJ62)
Yb^{177}	1.9 h (CorkJ56, AttH45) 2.4 h (BotW46)	☢ β^- (BotW46) Δ -50.8 (JohaH64, MTW)	A n-capt (MarsJK35, HevG36) chem, genet (BetR58) parent Lu^{177} (BetR58)	β^- 1.40 max γ Lu X-rays, 0.122 (3%), 0.151 (16%), 1.080 (5%), 1.241 (3%) e^- 0.059, 0.075, 0.088, 0.110, 0.140	$Yb^{176}(n, \gamma)$ (MarsJK35, HevG36, PoolM38a, BotW46, IngM47a)
Yb^{177m}	6.5 s (FetP62a, CamE59) 6.4 s (HoffK60a) others (DMatE49, KahJ51)	☢ IT (HoffK60a, FetP62a, DMatE49) Δ -50.5 (LHP, MTW)	A n-capt (DMatE49) n-capt, sep isotopes (HoffK60a, FetP62a)	γ Yb X-rays, 0.104 (65%), 0.228 (13%) e^- 0.043, 0.094, 0.167, 0.219	$Yb^{176}(n, \gamma)$ (HoffK60a, FetP62a, CamE59)
Yb^{m}	0.15 s (KahJ52)	☢ [IT] (KahJ51)	F n-capt (KahJ51)	γ 0.455 (KahJ52)	neutrons on Yb (KahJ51)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12} = 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{70}$Yb^{177} (or Er^{173}, Tm^{176})	2.0 m (WilleR60)	☢ IT or β^- (WilleR60)	F sep isotopes (WilleR60)	γ 0.18, 0.25, 0.36	neutrons on Yb^{176} (WilleR60)
$_{71}$Lu^{155}	0.07 s (MacfR65a)	☢ α (MacfR65a)	C cross bomb, excit (MacfR65a)	α 5.63	Sm^{144}(F^{19}, 8n) (MacfR65a)
Lu^{156}	0.23 s (MacfR65a)	☢ α (MacfR65a)	C cross bomb, excit (MacfR65a)	α 5.54	Sm^{144}(F^{19}, 7n) (MacfR65a)
Lu^{156}	0.5 s (MacfR65a)	☢ α (MacfR65a)	C cross bomb, excit (MacfR65a)	α 5.43	Sm^{144}(F^{19}, 7n) (MacfR65a)
Lu^{167}	54 m (HarmB59, ButeF60) 55 m (AroP58) others (BasiA60, BoncN60, KalyA59)	☢ EC (AroP58, HarmB59) β^+ ≈1% (BoncN60) Δ −57.1 (MTW, GromK62)	B chem, genet (AroP58, ButeF60) parent Yb^{167} (AroP58, ButeF60)	γ Yb X-rays, 0.030, 0.18–0.24 (complex), 0.278, 0.372, 0.402, 0.511 ($\gamma^{\pm}$) e$^-$ 0.020, 0.028, 0.039, 0.069, 0.076, 0.152, 0.178 β^+ 1.5 max daughter radiations from Yb^{167}	Yb^{168}(p, 2n) (HarmB59)
Lu^{168}	7.1 m (WilsRG60b) 7.0 m (MerE61)	☢ EC, no β^+ lim 1% (WilsRG60b) EC, β^+ ≈12% (MerE61) Δ −57 (MTW)	A sep isotopes, excit (WilsRG60b) chem (MerE61) daughter Hf^{168} (MerE61)	γ Yb X-rays, 0.087 (7%), 0.223, 0.71, 0.90 (10%), 0.99 (13%), 1.41, 1.81, 2.1 e$^-$ [0.026, 0.078, 0.085] β^+ 1.2 max	Yb^{168}(p, n) (WilsRG60b) Lu^{175}(p, 8n)Hf^{168}(EC) (MerE61)
Lu^{169}	34 h (DzhB64a) others (MerE61, DzhB59g, GoroG57b, NerW55)	☢ EC (GoroG57) β^+ (DzhB59g) Δ −58 (MTW)	A chem, excit (NerW55) chem, genet (GoroG57b, MerE61) parent Yb^{169} (GoroG57b, MerE61) parent Yb^{169m} (HarmB60) daughter Hf^{169} (MerE61)	γ Yb X-rays, 0.063, 0.111, 0.191, 0.577, many others to 2.2 e$^-$ 0.010, 0.014, 0.022, 0.026, 0.050, 0.053, 0.060, 0.066, 0.077, others to 2.2 β^+ 1.2 max daughter radiations from Yb^{169} daughter radiations from Yb^{169m} included in above listing	protons on Yb (HarmB59) daughter Hf^{169} (MerE61)
Lu^{169m}	2.7 m (BjoS65)	☢ IT (BjoS65) Δ −58 (LHP, MTW)	B excit, sep isotopes (BjoS65)	γ [Lu L X-rays] e$^-$ 0.019, 0.027	Yb^{170}(p, 2n) (BjoS65)
Lu^{170}	2.05 d (WilsRG60e) 2.0 d (DzhB64a) others (MerE61, MihJ57a, DzhB59g, WilkG51)	☢ EC (WilkG51) β^+ (DzhB59g, MerE61) Δ −57.1 (HansP65a, MTW)	A chem, excit (WilkG51) chem, mass spect (MicM56) daughter Hf^{170} (ValenJ62, MerE61)	γ Yb X-rays, 0.084 (13%), 0.193, 0.24, 1.01, 1.03, 1.17, 1.27, 1.41, 2.03, 2.32, 2.67, 2.89, 3.09, many others to 3.2 e$^-$ 0.023, 0.075, 0.082, others to 3.2 β^+ 2.4 max	Tm^{169}(α, 3n) (WilkG51) daughter Hf^{170} (ValenJ62, DzhB64a) protons on Yb (WilsRG60e, HarmB60)
Lu^{170m}	0.7 s (BjoS65)	☢ IT (BjoS65, ValenJ65) Δ −57.0 (LHP, MTW)	B excit, sep isotopes, genet energy levels (BjoS65)	γ Lu L X-rays e$^-$ 0.036, 0.044	daughter Hf^{170} (ValenJ65) Yb^{170}(p, n) (BjoS65)
Lu^{171}	8.3 d (WilsRG60h) 8.2 d (BonnN62) others (RaoC63, WilkG51, MihJ57a, ValenJ62)	☢ EC (WilkG51) β^+ ≈0.007% (VitV65a, LHP) Δ −58 (MTW)	A chem, excit (WilkG51) excit, sep isotopes (WilsRG60h) genet energy levels (IodM60a, ChupE58a) parent Yb^{171m} (MihJ57a, MihJ57, HarmB60) daughter Hf^{171} (WilkG51)	γ Yb X-rays, 0.019 (20%), 0.075 (8%, complex), 0.668 (14%), 0.741 (68%), 0.842 (7%) e$^-$ 0.010, 0.017, 0.057, 0.066, 0.074, others to 0.85	Tm^{169}(α, 2n) (WilkG51) Yb^{171}(p, n) (WilkG51, WilsRG60h)
Lu^{171m}	76 s (BjoS65)	☢ IT (BjoS65) Δ −58 (LHP, MTW)	B excit, sep isotopes (BjoS65) genet energy levels (BjoS65, BarnD65)	γ Lu X-rays, 0.071 (0.2%) e$^-$ 0.061, 0.069	daughter Hf^{171} (BarnD65) Yb^{171}(p, n) (BjoS65)
Lu^{172}	6.70 d (WilkG51, WilsRG60a) others (BonnN62, RaoC63)	☢ EC (WilkG51) Δ −57 (MTW)	A chem, excit (WilkG51) sep isotopes, excit (WilsRG60a) daughter Hf^{172} (WilkG51, ValenJ62b, RaoC63)	γ Yb X-rays, 0.079 (13%, complex), 0.182 (26%), 0.81 (21%), 0.90 (45%, complex), 1.09 (60%) e$^-$ 0.017, 0.029, 0.069, 0.077, 0.081, 0.120, others to 2.1	Yb^{172}(p, n) (WilkG51, WilsRG60a) Tm^{169}(α, n) (WilkG51)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{71}$Lu^{172m}	3.7 m (ValenJ62b)	☢ IT (ValenJ62b) Δ −57 (LHP, MTW)	B chem, genet (ValenJ62b) daughter Hf^{172} (ValenJ62b)	γ Lu L X-rays e^- 0.032, 0.040	daughter Hf^{172} (ValenJ62b)
Lu^{172}	4.0 h (WilkG51)	☢ β^+, EC (WilkG51)	G chem, excit (WilkG51) activity not observed (WilsRG60a)		alphas on Tm, protons on Lu (WilkG51)
Lu^{173}	1.37 y (BonnN62) 1.4 y (WilkG51, MihJ57a) 1.3 y (BicJ59, GrigE60a) 1.7 y (WilsRG60a) others (GoroG58a)	☢ EC (WilkG51) Δ −57.0 (MTW)	A chem, excit (WilkG51) sep isotopes (WilsRG60a) daughter Hf^{173} (WilkG51)	γ Yb L X-rays, Yb K X-rays (150%), 0.079 (14%), 0.101 (7%), 0.17 (5%, complex), 0.272 (18%), 0.637 (1.5%) e^- 0.017, 0.039, 0.068, 0.077, 0.090	Yb^{173}(p, n) (WilkG51, BicJ59, WilsRG60a) Lu^{175}(p, 3n)Hf^{173}(EC) (BicJ59, WilkG51)
Lu^{174}	3.6 y (BonnN62) >800 d (BalaV64) <<160 d (HarmB60) others (WilkG51, WilleR60)	☢ EC, no β^-, β^+ (WilsRG60) others (WilkG51) Δ −55.6 (MTW)	A chem, excit (WilkG51) excit, sep isotopes (WilsRG60) daughter Lu^{174m} (HarmB60)	γ Yb X-rays, 0.076 (6%), 1.24 (9%) e^- 0.015, 0.067, 0.074	Yb^{174}(p, n) (WilsRG60, HarmB60, PraH62)
Lu^{174m}	140 d (BonnN62) 150 d (BalaV64) others (WilkG51, WilleR60)	☢ IT (HarmB60, RomV60) EC (FunL65, RiccR65a) Δ −55.4 (LHP, MTW)	B chem, genet (HarmB60, RomV60) chem (BonnN62) parent Lu^{174} (HarmB60)	γ Lu L X-rays, 0.067, 0.176, 0.273, 0.994 e^- 0.004, 0.034, 0.050, 0.057 daughter radiations from Lu^{174}	Yb^{174}(p, n) (WilsRG60, HarmB60, PraH62)
Lu^{175}	$t_{1/2}$ (α) >1 × 10^{17} y sp act (PorsW54)	% 97.40 (HaydR50) 97.41 (CollT57) Δ −55.3 (MTW) σ_c 5 (to Lu^{176}) 18 (to Lu^{176m}) (GoldmDT64)			
Lu^{176}	2.2 × 10^{10} y sp act (DonhD64) 3.6 × 10^{10} y sp act (MNaiA61b, BrinGA65) 2.4 × 10^{10} y sp act (ArnJ54) 2.1 × 10^{10} y sp act (GloR57b) 4.6 × 10^{10} y sp act (DixD54) others (HerrW58a, LibW39a)	☢ β^-, no EC, lim 10% (ArnJ54) no EC (GloR57b) EC(K) 3% (DixD54) % 2.60 (HaydR50) 2.59 (CollT57) Δ −53.4 (MTW) σ_c 2100 (to Lu^{177}) ≈1 (to Lu^{177m}) (GoldmDT64)	A chem (HeyM38) mass spect (MattaJ39)	β^- 0.43 max e^- 0.023, 0.078, 0.086, 0.137 γ Hf X-rays, 0.088 (15%), 0.202 (85%), 0.306 (95%)	natural source
Lu^{176m}	3.69 h (SchmL60) others (BetR58, AttH45, BotW46)	☢ β^-, no IT (SchaG52) no β^+, lim 0.0005% (LanghH61b) Δ −53.1 (LHP, MTW)	A n-capt (MLenJ35b, MarsJK35) chem, excit (WilkG48a)	β^- 1.31 max e^- 0.023, 0.078, 0.086 γ Hf X-rays, 0.088 (10%)	Lu^{175}(n, γ) (MLenJ35b, MarsJK35, HevG36, FlaA43, BotW46, AttH45, SerL47b, AntoN50a)
Lu^{177}	6.74 d (SchmL60) others (BetR58, BotW46, WilkG48a, DouDG49, CorkJ49b, FlaA43, AttH45)	☢ β^- (BotW46) Δ −52.2 (MTW)	A n-capt (HevG36) mass spect (IngM47a) chem, excit (WilkG48a) daughter Yb^{177} (BetR58)	β^- 0.497 max γ Hf X-rays, 0.113 (2.8%), 0.208 (6.1%) e^- 0.048, 0.103, 0.111, 0.143	Lu^{176}(n, γ) (HevG36, FlaA43, AttH45, BotW46, SerL47b, AntoN50a, AlexP64)
Lu^{177m}	155 d (JorM62)	☢ β^- 78%, IT 22% (KriL64) Δ −51.3 (LHP, MTW)	A chem, n-capt, mass spect (JorM62) parent Hf^{177m} (BodE66)	γ Lu X-rays, Hf X-rays, 0.105 (13%), 0.113 (23%), 0.128 (17%), 0.153 (17%), 0.174 (13%), 0.208 (62%), 0.228 (37%), 0.281 (14%), 0.319 (10%), 0.327 (18%), 0.378 (29%), 0.414 (17%), 0.418 (21%), many others between 0.05 and 0.47 β^- [0.165 max] e^- very complex spectrum between 0 and 0.47 daughter radiations from Lu^{177} daughter radiations from Hf^{177m} included in above listing	Lu^{176}(n, γ) (JorM62, AlexP64)
Lu^{178}	30 m (KuroT61b)	☢ β^- (KuroT61b) Δ −50.0 (MTW)	F decay charac (KuroT61b)	β^- 2.25 max γ no γ	Hf^{179}(γ, p) (KuroT61b)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{71}$Lu^{178}	22.0 m (PouA60) 18.7 m (StriT57) 19 m (GleP61) 22 m (ButeF50) 16 m (KuroT61b) 30 m (BakH64a)	☢ β^- (KuroT61b) Δ −49.6 (LHP, MTW)	B chem (ButeF50) chem, genet energy levels (KuroT61b)	β^- 1.50 max e^- 0.023, 0.028, 0.077, 0.083, 0.091, 0.148, 0.204 γ Hf X-rays, 0.089, 0.214, 0.326, 0.427 daughter radiations from Hf^{178m} included in above listing	Ta^{181}(n, α) (GleP61, PouA60, BakH64a, StriT57)
Lu^{178}	5 m (BakH64a)	☢ β^- (BakH64a)	F chem (BakH64a)	β^- 2.25 γ 0.090, 0.22, 0.33, 0.43	Ta^{181}(n, α) (BakH64a)
Lu^{179}	4.6 h (StenW63) 7.5 h (KuroT61b)	☢ β^- (KuroT61b) Δ −48.9 (MTW)	B decay charac (KuroT61b) chem, sep isotopes, decay charac (StenW63)	β^- 1.35 max γ 0.213	Hf^{180}(γ, p) (StenW63, KuroT61b)
Lu^{180}	2.5 m (TakaK61)	☢ β^- (TakaK61) Δ −46.2 (MTW)	F decay charac (TakaK61)	β^- 3.3 max γ no γ	Hf^{180}(n, p) (TakaK61)
$_{72}$Hf^{157}	0.12 s (MacfR65a)	☢ α (MacfR65a)	C cross bomb, excit (MacfR65a)	α 5.68	Sm^{144}(Ne^{20}, 7n) (MacfR65a)
Hf^{158}	3 s (MacfR65a)	☢ α (MacfR65a)	C cross bomb, sep isotopes (MacfR65a)	α 5.27	Sm^{144}(Ne^{20}, 6n) (MacfR65a)
Hf^{168}	22 m (MerE61)	☢ [EC], β^+ ? ≈2% (MerE61)	B chem, genet (MerE61) parent Lu^{168} (MerE61)	γ Lu X-rays, 0.129, 0.17 β^+ ? 1.7 max daughter radiations from Lu^{168}	Lu^{175}(p, 8n) (MerE61)
Hf^{169}	1.5 h (MerE61) others (WilkG51)	☢ EC, β^+ (MerE61)	B chem, genet (MerE61) parent Lu^{169} (MerE61)	γ Lu X-rays, 0.115 β^+ 1.3 max daughter radiations from Lu^{169}	Lu^{175}(p, 7n) (MerE61)
Hf^{170}	12.2 h (ValenJ62) 9 h (MerE61)	☢ EC (ValenJ62)	A chem, genet (MerE61) chem, genet, mass spect (ValenJ62) parent Lu^{170} (MerE61, ValenJ62)	γ Lu X-rays, 0.120, 0.165, 0.99, 1.28, 0.65, 2.03, 2.36, 2.52, 2.94 e^- 0.035, 0.057, 0.102, 0.145, others between 0 and 3 daughter radiations from Lu^{170}	Lu^{175}(p, 6n) (MerE61, ValenJ62)
Hf^{171}	10.7 h (ValenJ62) 16.0 h (WilkG51) 12 h (NerW55) 13 h (BaranV59a) others (BrabV61a, RaoC63)	☢ EC (WilkG51)	B chem, genet, excit (WilkG51) chem, mass spect (ValenJ62) parent Lu^{171} (WilkG51)	γ Lu X-rays, 0.122, 0.188, 0.29, 0.34, 0.47, 0.66, 0.86, 1.07 daughter radiations from Lu^{171}	Lu^{175}(p, 5n) (WilkG51, ValenJ62) alphas on Yb (WilkG51)
Hf^{172}	5 y (RaoC63, WilkG51)	☢ EC (WilkG51)	A chem, genet (WilkG51) chem, sep isotopes (ValenJ62b) parent Lu^{172} (WilkG51, ValenJ62b, RaoC63) parent Lu^{172m} (ValenJ62b)	γ Lu X-rays, 0.024 (22%), 0.082 (10%), 0.125 (21%, complex) e^- 0.014, 0.018, 0.032, 0.040, 0.063 daughter radiations from Lu^{172} daughter radiations from Lu^{172m} included in above listing	Lu^{175}(p, 4n) (WilkG51) alphas on Yb (WilkG51, ValenJ62b)
Hf^{173}	23.6 h (WilkG51) 24 h (RaoC63, ValenJ62a, MalyT62, BaranV59a) others (NerW55, WapA54c)	☢ EC (WilkG51)	A chem, excit, genet (WilkG51) parent Lu^{173} (WilkG51) daughter Ta^{173} (FalK60, RaoC63, MalyT62)	γ Lu X-rays, 0.13 (96%, complex), 0.162 (5%), 0.30 (52%, complex), 0.55 (1.1% complex), 0.898 (1.9%), 1.04 (1.0%, complex), 1.20 (0.4%, complex) e^- 0.060, 0.072, 0.076, 0.113, 0.127, others between 0 and 1.1	Lu^{175}(p, 3n) (WilkG51, BicJ59) alphas on Yb (WilkG51, ValenJ62a)
Hf^{174}	2.0 × 10^{15} y sp act (MacfR61a) 4 × 10^{15} y sp act (RieW59)	☢ α (RieW59, MacfR61a) % 0.163 (WhiF56) 0.20 (ReynJH53) Δ −55.6 (MTW) σ_c 400 (GoldmDT64)	A sep isotopes, decay charac (MacfR61a)	α 2.50	
Hf^{175}	70 d (WilkG49)	☢ EC (WilkG49) Δ −54.7 (FunL65f, MTW)	A chem, excit (WilkG49) n-capt, sep isotopes (BursS51) mass spect (HedA51) daughter Ta^{175} (RaoC63, FalK60)	γ Lu X-rays, 0.089 (3.4%), 0.343 (85%), 0.433 (1.4%) e^- 0.026, 0.079, 0.280, 0.333	Hf^{174}(n, γ) (HedA51, HatE56, MizJ55) Lu^{175}(d, 2n), Lu^{175}(p, n) (WilkG49)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{72}$Hf^{176}		% 5.21 (WhiF56) 5.23 (ReynJH53) Δ −54.4 (MTW) σ_c <30 (GoldmDT64)			
Hf^{177}		% 18.56 (WhiF56) 18.6 (ReynJH53) Δ −52.7 (MTW) σ_c 370 (to Hf^{178}) 1.4 (to Hf^{178m}) (GoldmDT64)			
Hf^{177m}	1.1 s (BodE66)	☢ IT (BodE66) Δ −51.4 (LHP, MTW)	A chem, genet (BodE66) daughter Lu^{177m} (BodE66)	γ Hf X-rays, 0.105 (17%), 0.113 (30%), 0.128 (21%), 0.153 (22%), 0.174 (16%), 0.208 (81%), 0.228 (48%), 0.281 (18%), 0.327 (23%), 0.378 (37%), 0.418 (27%), many others between 0 and 0.47 e^- very complex spectrum between 0 and 0.47	daughter Lu^{177m} (BodE66)
Hf^{178}		% 27.1 (WhiF56) 27.2 (ReynJH53) Δ −52.3 (MTW) σ_c 30 (to Hf^{179}) 50 (to Hf^{179m}) (GoldmDT64)			
Hf^{178m}	4.3 s (AlexKF62) 4.8 s (FelF58) 3.5 s (CamE59, FetP62a)	☢ IT (FelF58) Δ −51.1 (MTW)	A chem, genet (FelF58) n-capt, sep isotopes (FetP62a) daughter 2.1 h Ta^{178} (FelF58)	γ Hf X-rays, 0.089 (54%), 0.093 (14%), 0.214 (75%), 0.326 (94%), 0.427 (97%) e^- 0.023, 0.028, 0.077, 0.083, 0.091, 0.148, 0.204	daughter Ta^{178} (FelF58) Hf^{177}(n, γ) (FetP62a)
Hf^{179}		% 13.75 (WhiF56) 13.7 (ReynJH53) Δ −50.3 (MTW) σ_c 65 (to Hf^{180}) 0.2 (to Hf^{180m}) (GoldmDT64)			
Hf^{179m}	18.6 s (HoffK59) others (FlaA44a, DMatE51a, AlexKF62)	☢ IT (FlaA46) Δ −49.9 (LHP, MTW)	A n-capt (FlaA44a) n-capt, sep isotopes (BursS51, DMatE51a)	γ Hf X-rays, 0.217 (94%) e^- 0.096, 0.150	Hf^{178}(n, γ) (FlaA44a, FlaA46, DMatE51a, BursS51)
Hf^{180}		% 35.22 (WhiF56) Δ −49.5 (MTW) σ_c 10 (GoldmDT64)			
Hf^{180m}	5.5 h (BursS51) others (RaoC63)	☢ IT (BursS51) no β^-, lim 5% (GallC62) Δ −48.4 (LHP, MTW)	A chem, n-capt, sep isotopes (BursS51) genet energy levels (MihJ54b)	γ Hf X-rays, 0.058 (48%), 0.093 (16%), 0.215 (82%), 0.333 (93%), 0.444 (80%), 0.501 (17%) e^- 0.028, 0.047, 0.055, 0.083, 0.091, 0.150, 0.206, 0.267	Hf^{179}(n, γ) (BursS51)
Hf^{181}	42.5 d (LindnM60) 44.6 d (WriH57) 45.5 d (CaliJ59) others (MurH53, CorkJ50d, BeneJ48a, SerL47b)	☢ β^- (HevG38) Δ −47.41 (MTW) σ_c ≈40 (GoldmDT64)	A chem, n-capt (HevG38) mass spect (HedA51) sep isotopes, n-capt (BursS51)	β^- 0.41 max e^- 0.066, 0.069, 0.122, 0.415 γ Ta X-rays, 0.133 (48%, complex), 0.346 (13%), 0.482 (81%)	Hf^{180}(n, γ) (HevG38, SerL47b, BursS51, LindM60)
Hf^{182}	9 x 10^{6} y sp act (HutWH61, WingJ61) ≈8 x 10^{6} y sp act (NauR61)	☢ β^- (HutWH61, WingJ61, NauR61) Δ −45.8 (LHP, MTW)	A chem, mass spect, genet (HutW61, WingJ61, NauR61) parent Ta^{182} (HutW61, WingJ61, NauR61)	β^- [0.5 max] γ 0.271 (84%) daughter radiations from Ta^{182}	Hf^{180} + 2n (HutW61, WingJ61, NauR61)
Hf^{183}	65 m (BlacJe65) 64 m (GatO56, GatO58)	☢ β^- (GatO56, GatO58) Δ −43.0 (MTW)	D chem (GatO56, GatO58)	β^- 1.6 max γ 0.46 (I 58), 0.82 (I 100)	W^{186}(n, α) (GatO56, GatO58, BlacJe65)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12} = 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{73}$Ta^{172}	44 m (AboH64a) 24 m (ButeF61)	☢ β$^+$, EC (AboH64a)	B chem (ButeF61) chem, mass spect (AboH64a)	γ Hf X-rays, 0.092, 0.208, 0.511 (γ$^\pm$), others to 3.3	protons on Hf (AboH64a, ButeF61)
Ta^{173}	3.7 h (FalK60, SanA63, RaoC63) 3.5 h (MalyT62) 2.5 h (HarmB60)	☢ EC, β$^+$ (FalK60) EC, no β$^+$ (SanA63)	A chem, excit, genet (FalK60, RaoC63) chem, genet (MalyT62) parent Hf^{173} (FalK60, RaoC63, MalyT62) daughter W^{173} (SanA63)	γ Hf X-rays, 0.090 (complex), 0.170 (complex), 0.64, 1.00 e$^-$ 0.059, 0.069, 0.095, 0.107, 0.161 daughter radiations from Hf^{173}	Ho^{165}(N^{14}, 6n)W^{173}(EC) (FalK60) protons on Ta^{181} (RaoC63, SanA63)
Ta^{174}	1.2 h (DemeI65) 1.3 h (FalK60, RaoC63) 1.1 h (ButeF61)	☢ EC, β$^+$ (FalK60)	A chem, excit (FalK60, RaoC63) chem, mass spect (AboH65) daughter W^{174} (DemeI65)	γ Hf X-rays, 0.091, 0.125, 0.160, 0.205, 0.280, 0.350, 0.511 (γ$^\pm$) e$^-$ 0.026, 0.081, 0.089	Ho^{165}(N^{14}, 5n)W^{174}(EC) (FalK60) protons on Hf (HarmB60, ButeF61) protons on Ta^{181} (RaoC63)
Ta^{175}	10.5 h (SanA63) 11 h (FalK60, RaoC63)	☢ EC (FalK60)	A chem, cross bomb, excit, genet (FalK60) chem, excit, genet (RaoC63) parent Hf^{175} (RaoC63, FalK60) daughter W^{175} (SanA63)	γ Hf X-rays, 0.08, 0.13, 0.21, 0.27, 0.35, 0.45, 0.60, 0.83, 1.2, 1.4, 1.7, all complex e$^-$ 0.016, 0.039, 0.061, 0.070, 0.116, 0.202, others between 0 and 1.6	Lu^{175}(α, 4n) (FalK60) Hf^{176}(p, 2n) (HarmB60) Ho^{165}(N^{14}, 4n)W^{175}(EC) (FalK60) protons on Ta^{181} (RaoC63, SanA63)
Ta^{176}	8.0 h (WilkG50d)	☢ EC (WilkG50d) no β$^+$, lim 0.2% (FelF56) Δ −51 (NDS, MTW)	A chem, excit (WilkG48a, WilkG50d) genet energy levels (FelF56) daughter W^{176} (WilkG50d)	γ Hf X-rays, 0.088, 0.202, many others to 3.0 e$^-$ 0.023, 0.078, 0.086, 0.137, others to 3.0	Lu^{175}(α, 3n) (WilkG50d, VerhH63, HasA63) Hf^{176}(p, n) (HarmB60)
Ta^{177}	56.6 h (WestH61) 56 h (RaoC63) 53 h (WilkG50d)	☢ EC (WilkG50d) Δ −51.6 (MTW)	A chem, excit (WilkG48a, WilkG50d) genet energy levels (WestH61, HarmB60)	γ Hf X-rays, 0.113 (6%), 0.208 (1.0%), 0.425 (0.13%), 0.509 (0.10%), 0.746 (0.22%), 1.058 (0.30%), others between 0.07 and 0.95 e$^-$ 0.048, 0.102, 0.111, others between 0 and 1.06	Lu^{175}(α, 2n) (WilkG50d, WestH61) protons on Hf (WilkG50d, HarmB60) Ta^{181}(p, 5n)W^{177}(EC) (WilkG50d)
Ta^{178}	9.35 m (WilkG50d) 9.5 m (CarvJ58)	☢ EC 99%, β$^+$ 1% (GallC61a) others (FelF58, BisA56b, WilkG50d) Δ −50.4 (MTW)	A chem, genet (WilkG50d) daughter W^{178} (WilkG50d)	γ Hf X-rays, 0.093 (↑ 100), 0.511 (γ$^\pm$, ↑ 10), 1.10 (↑ 11), 1.18 (↑ 4, complex), 1.35 (↑ 46, complex), 1.45 (↑ 9, complex) β$^+$ 0.89 max e$^-$ 0.028, 0.082	daughter W^{178} (WilkG50d, GallC61a, BodE62, KarlE62a)
Ta^{178}	2.1 h (WilkG50d, RaoC63) 2.5 h (CarvJ58)	☢ EC, no β$^+$, lim 2% (CarvJ58) EC ≈97%, β$^+$ ≈3% (WilkG50d)	A chem, excit (WilkG50d, RaoC63) chem, cross bomb, genet (FelF58) parent Hf^{178m} (FelF58)	γ Hf X-rays, 0.089 (54%), 0.093 (14%), 0.214 (75%), 0.328 (120%, complex), 0.427 (97%) e$^-$ 0.023, 0.028, 0.077, 0.083, 0.091, 0.148, 0.204, 0.263 daughter radiations from Hf^{178m} included in above listing	Lu^{175}(α, n) (WilkG50d, GallC62a, FelF58) deuterons on Hf (FelF58) protons on Hf (WilkG50d)
Ta^{179}	≈600 d (WilkG50d)	☢ EC (WilkG50d) Δ −50.2 (MTW)	B chem, excit (WilkG50d, RaoC63) excit (CarvJ58)	γ Hf X-rays	protons on Ta^{181} (RaoC63) Lu^{176}(α, n) (WilkG50d)
Ta^{180}	$t_{1/2}$ (β$^-$): >1 x 10^{12} y sp act (CarvJ58) >1 x 10^{13} y sp act (BaumE58) $t_{1/2}$ (EC): >2 x 10^{13} y sp act (BaumE58) >4 x 10^{9} y sp act (CarvJ58) others (EberP55, EberP58)	% 0.0123 (WhiF56) Δ −48.86 (MTW)			
Ta^{180m}	8.15 h (BrowHN51) 8.00 h (WilkG50d) 8.1 h (RaoC63) others (OldO38)	☢ EC 87%, β$^-$ 13% (GallC62) EC ≈79%, β$^-$ ≈21%, no β$^+$, lim 0.005% (BrowHN51) Δ −48.65 (LHP, MTW)	A chem, excit (OldO38)	β$^-$ 0.71 max e$^-$ 0.028, 0.083, 0.091 γ Hf X-rays, 0.093 (4%), 0.103 (0.6%)	Hf^{180}(d, 2n) (GallC62) Ta^{181}(n, 2n) (PoolM37, OldO38, WilkG50d) Ta^{181}(γ, n) (GelK60, GusaM58)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV (C^{12} = 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$\underline{_{73}\mathrm{Ta}^{181}}$		% 99.9877 (WhiF56, WhiF55) 100 (WhiJ48) Δ -48.43 (MTW) σ_c 21 (to Ta^{182}) 0.07 (to Ta^{182m}) (GoldmDT64)			
Ta^{m}	0.33 s (CamE49, GooM50, KahJ51)	☢ IT (GooM50)	E excit (CamE49) critical abs (GooM50)	γ Ta L X-rays	neutrons on Ta (CamE49, GooM50, KahJ51)
Ta^{182}	115.1 d (WriH57) others (EicG52, SinW51, SerL47b)	☢ β^- (HouF40) Δ -46.35 (HansP64, MTW) σ_c 8000 (GoldmDT64)	A chem, n-capt (FomV36, OldO38) daughter Hf^{182} (HutW61, WingJ61, NauR61)	β^- 1.71 max (0.3%), 0.522 max e^- 0.030, 0.044, 0.054, 0.073, 0.089, 0.110, many others between 0 and 1.6 γ W X-rays, 0.068 (42%), 0.100 (14%), 0.152 (7%), 0.222 (8%), 1.122 (34%), 1.189 (16%), 1.222 (27%), 1.231 (13%), many others between 0 and 1.6	Ta^{181}(n, γ) (FomV36, OldO38, HouF40, SerL47b, MeiL48)
Ta^{182m}	16.5 m (HoleN48b) 16.2 m (SerL47b) others (WilkG50d)	☢ IT (HoleN48b) no β^- (SunA61) Δ -45.84 (LHP, MTW)	A chem, n-capt (SerL47b, HoleN48b)	γ Ta X-rays, 0.147 (40%), 0.172 (40%), 0.184 (20%), 0.319 (5%), 0.356 (0.3%) e^- 0.080, 0.105, 0.117, 0.173	Ta^{181}(n, γ) (SerL47b, HoleN48b, SunA61)
Ta^{183}	5.0 d (PoeA55) 5.2 d (MurJ55, DMonJ53) others (SumO57a, MosA51)	☢ β^- (ButeF50, PoeA55) Δ -45.20 (MTW)	A chem, excit (ButeF50) n-capt, chem, genet energy levels (MurJ55) parent W^{183m} (GallC61)	β^- 0.62 max γ W X-rays, 0.046 (5%), 0.053 (5%), 0.099 (7%), 0.108 (11%), 0.161 (17%, complex), 0.246 (33%, complex), 0.30 (11%, complex), 0.354 (11%) e^- 0.034-0.043, 0.050, 0.073, 0.088, 0.093, 0.177, many others between 0 and 0.40 daughter radiations from W^{183m} included in above listing	Ta^{181}(n, γ)Ta^{182}(n, γ) (MurJ55)
Ta^{184}	8.7 h (ButeF55a)	☢ β^- (ButeF55a) Δ -42.9 (MTW)	B chem, sep isotopes (ButeF55a)	β^- 2.64 max (0.2%), 1.76 max (0.9%), 1.19 max e^- [0.042, 0.100] γ W X-rays, 0.111 (21%), 0.16 (7%), 0.21 (7%), 0.25 (42%), 0.30 (24%), 0.41 (71%), 0.53 (19%), 0.79 (16%, complex), 0.90 (49%, complex), 0.95 (15%), 1.16 (12%)	W^{186}(d, α) (VerhH64) W^{184}(n, p) (ButeF55a)
Ta^{185}	50 m (PoeA55) 48 m (MosA51, ButeF50) others (DufR50)	☢ β^- (DufR50) Δ -41.3 (NDS, MTW)	B chem, excit (ButeF50) excit, sep isotopes (DufR50) not parent W^{185m} (PoeA55)	β^- 1.7 max γ W X-rays, 0.075 (5%), 0.100 (6%), 0.175 (60%), 0.245 (5%)	W^{186}(γ, p) (DufR50, ButeF50, MoriH60a) W^{186}(n, pn) (PoeA55)
Ta^{186}	10.5 m (PoeA55)	☢ β^- (PoeA55) Δ -38.7 (MTW)	C sep isotopes, cross bomb (PoeA55)	β^- 2.2 max γ W X-rays, 0.123 (18%), 0.20 (74%), 0.30 (18%), 0.41 (15%), 0.51 (33%), 0.61 (33%), 0.73 (48%), 0.94 (11%)	W^{186}(n, p) (PoeA55)
$_{74}\mathrm{W}^{160?}$		☢ α (MacfR65a)	F excit (MacfR65a)	α 5.75	S^{32} on Sm^{144} (MacfR65a)
W^{173}	16.5 m (SanA63)	☢ EC (SanA63)	B chem, excit, genet (SanA63) parent Ta^{173} (SanA63)		Ta^{181}(p, 9n) (SanA63)
W^{174}	31 m genet (DemeI65)	☢ [EC] (DemeI65)	B chem, genet (DemeI65) parent Ta^{174} (DemeI65)		C^{12} on Er (DemeI65)
W^{175}	34 m (SanA63)	☢ EC (SanA63)	A chem, mass spect, genet (SanA63) parent Ta^{175} (SanA63)	γ Ta X-rays, 0.26, 0.80, 1.3, 1.6 daughter radiations from Ta^{175}	Ta^{181}(p, 7n) (SanA63)
W^{176}	2.3 h (ValenJ63) 2.7 h (RaoC63) others (GrigE62)	☢ EC 99+%, β^+ ≈0.5% (WilkG50d) Δ -50 (NDS, MTW)	A chem, genet (WilkG50d, GrigE62) chem, mass spect (ValenJ63) parent Ta^{176} (WilkG50d)	γ Ta X-rays, 0.034, 0.100 e^- 0.017, 0.023, 0.027, 0.033, 0.050, 0.083 daughter radiations from Ta^{176}	Ta^{181}(p, 6n) (RaoC63, WilkG50d)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{74}W^{177}$	135 m (SanA63) 130 m (WilkG50d) 132 m (RaoC63) others (MalyT63a)	☢ EC (WilkG50d) Δ −50 (NDS, MTW)	A chem, genet (WilkG50d) chem, mass spect (SanA63) chem, excit (RaoC63) parent Ta^{177} (WilkG50d) daughter Re^{177} (HaldB57)	γ Ta X-rays, 0.20, 0.42, 0.62, 0.83, 1.00 e^- 0.020, 0.028, 0.048, 0.059, 0.068, 0.075, 0.088, 0.119, 0.360 daughter radiations from Ta^{177}	Ta^{181}(p, 5n) (RaoC63, SanA63, WilkG50d)
W^{178}	21.5 d (WilkG50d) 22.0 d (BisA56b)	☢ EC (WilkG50d) Δ −50 (NDS, MTW)	A chem (WilkG50d) chem, excit (RaoC63) parent 9.35 m Ta^{178} (WilkG50d)	γ Ta X-rays daughter radiations from 9.35 m Ta^{178}	Ta^{181}(p, 4n) (RaoC63, WilkG50d)
W^{179}	37.5 m (ValenJ63a) 38 m (SanA63) others (RaoC63, WilkG50d, RocT56)	☢ EC (WilkG50d) Δ −49 (NDS, MTW)	A chem, excit (RaoC63, WilkG50d) chem, sep isotopes (HarmB60) chem, mass spect (SanA63, ValenJ63a)	γ Ta X-rays, 0.031 (22%) e^- 0.020, 0.029	Ta^{181}(p, 3n) (RaoC63, WilkG50d) W^{180}(p, 2n)Re^{179}(EC) (HarmB60)
W^{179m}	5.2 m (WilkG50d) ≈7 m (RocT56) activity not observed (SofS55)	☢ IT (HarmB60) Δ −49 (NDS, MTW)	B chem, excit (WilkG50d) genet energy levels (HarmB60)	γ W X-rays, 0.222 e^- 0.152, 0.211 daughter radiations from W^{179}	daughter Re^{179} (HarmB60) Ta^{181}(p, 3n) (WilkG50d)
W^{180}	$t_{1/2}$ (α): >1.1×10^{15} y sp act (BearG60) >9×10^{14} y sp act (MacfR61a)	% 0.135 (WilliD46) Δ −49.37 (MTW) σ_c <20 (GoldmDT64)			
$W^{[180]}$	$t_{1/2}$(α) <2×10^{17} y sp act (PorsW56)	☢ α (PorsW56)	G (PorsW56) activity not observed (BearG60, MacfR61a)	α 3.0	natural source (PorsW56)
W^{181}	140 d (RaoC63, WilkG47, SinB59) 120 d (GodK61) 126 d (KreW60) 145 d (BisA56b)	☢ EC (WilkG47) no β^+ (BisA56b, BisA55) Δ −48.24 (MTW)	A chem, excit (WilkG47) chem, n-capt (LindnM51a) daughter Re^{181} (GallC57)	γ Ta X-rays, 0.006 (1%), 0.136 (0.1%), 0.152 (0.1%) e^- 0.004, 0.006	Ta^{181}(d, 2n) (WilkG47) Ta^{181}(p, n) (MuiA61) W^{180}(n, γ) (MuiA61, LindnM51a, CorkJ53d)
W^{182}	$t_{1/2}$ (α) >2×10^{17} y sp act (BearG60)	% 26.4 (WilliD46) Δ −48.16 (MTW) σ_c 20 (to W^{183}) 0.5 (to W^{183m}) (GoldmDT64)			
W^{183}	$t_{1/2}$ (α) >1.1×10^{17} y sp act (BearG60)	% 14.4 (WilliD46) Δ −46.27 (MTW) σ_c 11 (GoldmDT64)			
W^{183m}	5.3 s (GallC61) 5.1 s (SchmW61) 5.5 s (DMatE49)	☢ IT (DMatE49) Δ −45.96 (LHP, MTW)	A sep isotopes, n-capt (DMatE49) chem, genet, genet energy levels (GallC61) daughter Ta^{183} (GallC61)	γ W X-rays, 0.046 (8%), 0.053 (11%), 0.099 (9%), 0.102 (4%), 0.108 (19%), 0.160 (6%) e^- 0.034, 0.040	daughter Ta^{183} (GallC61) W^{182}(n, γ) (SchmW61, DMatE49)
W^{184}		% 30.6 (WilliD46) Δ −45.62 (MTW) σ_c 2.1 (to W^{185}) 0.01 (to W^{185m}) (GoldmDT64)			
W^{185}	75 d (AndeR64, FajK40a, KreW55) others (ThirH57, GodK61, DoyW63a)	☢ β^- (MinaO40) Δ −43.30 (MTW)	A chem, excit, n-capt (MinaO40) mass spect (BisA58a)	β^- 0.429 max average β^- energy: 0.14 calorimetric (ShimN56a) γ no γ	W^{184}(n, γ) (MinaO40, FajK40a, SerL47b, CorkJ49a) Re^{187}(d, α) (FajK40a)
W^{185m}	1.62 m (PoeA55) 1.55 m (MangS62) 1.85 m (DufR50)	☢ IT (DufR50) Δ −42.93 (LHP, MTW)	B excit, sep isotopes (DufR50, PoeA55) not daughter Ta^{185} (PoeA55)	γ W X-rays, 0.075 (! 8), 0.100 (! 16), 0.13 (! 70), 0.17 (! 100)	W^{184}(n, γ) (PoeA55) W^{186}(γ, n) (DufR50, MoriH60a)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M–A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{74}$W^{186}	t$_{1/2}$ (ββ) >6 x 10^{15} y sp act (FremJ52)	% 28.4 (WilliD46) Δ -42.44 (MTW) σ_c 40 (GoldmDT64)			
W^{187}	23.9 h (EicG53) 23.7 h (AndeR64) 24.0 h (WriH57) others (MinaO40, CorkJ53, FajK40a)	☢ β$^-$ (MinaO40) Δ -39.83 (MTW) σ_c ≈90 (GoldmDT64)	A chem, n-capt (AmaE35) chem, n-capt, excit (MinaO40)	β$^-$ 1.31 max (15%), 0.63 max e$^-$ 0.063, 0.122, others between 0 and 0.8 γ Re X-rays, 0.072 (11%), 0.134 (9%), 0.479 (23%), 0.552 (5%), 0.618 (6%), 0.686 (27%), 0.773 (4%)	W^{186}(n, γ) (MinaO40, AmaE35, MLenJ35, FajK40a, SerL47b, CorkJ49a
W^{188}	69.4 d (RoyJ62) others (LindnM51a)	☢ β$^-$ (LindnM51a) Δ -38.44 (BursS64, MTW)	A chem, genet (LindnM51a, RoyJ62) parent Re^{188} (RoyJ62, LindnM51a, LindnM51)	β$^-$ 0.349 max γ Re X-rays, 0.227 (0.22%), 0.290 (0.46%) daughter radiations from Re^{188}	W^{186}(n, γ)W^{187}(n, γ) (LindnM51a, LindnM51, RoyJ62)
W^{189}	11.5 m (KauP65a) 11 m (FleJ63)	☢ β$^-$ (FleJ63) Δ -35.3 (KauP65a, MTW)	A chem, sep isotopes, genet (FleJ63) chem, genet (KauP65a) parent Re^{189} (FleJ63, KauP65a)	β$^-$ 2.5 max (weak), 2.0 max γ Re X-rays, 0.032 (?), 0.130 (! 12), 0.178 (! 13), 0.258 (! 100), 0.417 (! 96), 0.55 (! 28), 0.86 (! 20) 0.96 (! 17)	Os^{192}(n, α) (FleJ63)
$_{75}$Re^{177}	17 m (HaldB57)	☢ β$^+$ (HaldB47), [EC] Δ -47 (NDS, MTW)	B chem, genet (HaldB57) parent W^{177} (HaldB57)	γ [W X-rays, 0.511 (γ$^{\pm}$)] daughter radiations from W^{177}	protons on W (HaldB57)
Re^{178}	15 m (HaldB57)	☢ β$^+$ (HaldB57), [EC]	D chem, sep isotopes (HaldB57)	β$^+$ 3.1 max γ [W X-rays, 0.511 (γ$^{\pm}$)]	protons on W, Re (HaldB57)
Re^{179}	20 m (HarmB60) 18 m (FosJ58)	☢ EC (HarmB60) Δ -46 (NDS, MTW)	B chem, sep isotopes (HarmB60) others (FosJ58)	γ W X-rays daughter radiations from W^{179m} W^{179}	W^{180}(p, 2n) (HarmB60)
Re^{180}	2.4 m (FiscV55)	☢ β$^+$, EC (FiscV55)	C excit (FiscV55)	β$^+$ 1.1 max γ [W X-rays], 0.11, 0.511 (γ$^{\pm}$), 0.88	W^{182}(p, 3n) (FiscV55)
Re^{180}	20 h (HaldB57)	☢ β$^+$ (HaldB57), [EC]	D chem, decay charac, cross bomb (HaldB57)	β$^+$ 1.9 max γ [W X-rays, 0.511 (γ$^{\pm}$)]	protons on W, Re (HaldB57)
Re^{180}	18 m (FosJ58)	☢ [EC] (FosJ58)	G chem, excit, sep isotopes (FosJ58) activity assigned to Re^{179} (HarmB60)		protons on Re (FosJ58)
Re^{181}	18 h (GranG63) 19 h (FosJ58) 20 h (GallC57)	☢ EC (GallC57) Δ -47 (NDS, MTW)	B chem, excit, genet (GallC57) parent W^{181} (GallC57) daughter 23 m Os^{181} (FosJ58) daughter 2.7 h Os^{181} (SurY60)	γ W X-rays, 0.365, many others between 0 and 1.5 e$^-$ 0.008, 0.040, 0.053, 0.296, many others between 0 and 1.5	Ta^{181}(α, 4n) (GallC57) W^{182}(p, 2n) (HarmB60)
Re^{182}	12.7 h (WilkG50) 13 h (GallC59)	☢ EC (WilkG50) β$^+$ 0.3% (BadN63) Δ -45.30 (MTW)	A chem, excit (WilkG50) chem, genet energy levels (GallC59) daughter Os^{182} (StovB50, FosJ58)	γ W X-rays, 0.068, 0.100, 1.122, 1.189, 1.23 (complex), 2.01, 2.05, many others between 0 and 2.05 β$^+$ 1.74 max e$^-$ 0.015, 0.031, 0.056, 0.089, 0.098, many others between 0 and 2.05	Ta^{181}(α, 3n) (WilkG50, GallC59) W^{182}(p, n) (WilkG50, HarmB61) daughter Os^{182} (FosJ58, StovB50)
Re^{182}	64.0 h (WilkG50) 60 h (GallC58a)	☢ EC (WilkG50) no β$^+$, lim 5 x 10^{-4}% (BadN63)	A chem, excit (WilkG50) chem, genet energy levels (GallC58a)	γ W X-rays (very strong), 0.068, 0.100, 0.15-0.36 (complex), 1.08, 1.112 (complex), 1.19, 1.22 (complex), 1.43, many others between 0 and 1.4 e$^-$ 0.015, 0.031, 0.044, 0.061, 0.089, 0.098, 0.100, 0.122, 0.160, 0.187, many others between 0 and 1.4	Ta^{181}(α, 3n) (WilkG50, GallC58a) W^{182}(p, n) (WilkG50, HarmB61)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M–A), MeV (C^{12}≡0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{75}$Re^{183}	71 d (BliP65, GallC58) 68 d (FosJ58) others (ThuS56, TurS51, StovB50)	☢ EC (WilkG50) Δ -45 (MTW)	A chem, excit (WilkG50) chem, genet energy levels (ThuS56) daughter Os^{183} (StovB50)	γ W X-rays, 0.046, 0.053, 0.109 (complex), 0.209 (strong), 0.246, 0.292 e^- 0.030, 0.034, 0.040, 0.088, 0.093, many others between 0 and 0.40	Ta^{181}(α, 2n) (WilkG50, ThuS56)
Re^{184}	38 d (BodE60, DzhB62b) 34 d (BliP65) 33 d (JohnN63) others (WilkG50, TurS51)	☢ EC (WilkG50) Δ -44 (MTW)	A chem, excit (FajK40a) chem, excit (WilkG50) chem, genet energy levels (GallC58)	γ W X-rays, 0.111, 0.78 (complex), 0.90 (complex) e^- 0.042, 0.100	Ta^{181}(α, n) (WilkG50) deuterons on W (BisK63a, BodE60, DzhB62b, GallC58) protons on W (WilkG50, HarmB64) Re^{185}(n, 2n) (GallC58, JohnN63)
Re^{184m}	169 d (JohnN63) 160 d (HarmB64) 166 d (BliP65) others (DzhB62b)	☢ IT 70%, EC 30% (HarmB64) Δ -44 (LHP, MTW)	A chem, genet energy levels (JohnN63, HarmB64)	γ Re X-rays, W X-rays, 0.111, 0.78 (complex), 0.90 (complex) e^- 0.035, 0.042, 0.073, 0.081, 0.100 daughter radiations from Re^{184}	See Re^{184}
Re$^{184?}$	2.2 d (WilkG50)	☢ EC or IT (WilkG50)	D chem, excit (WilkG50)	γ 0.159	Ta^{181}(α, n) (WilkG50) W^{184}(p, n) (WilkG50)
Re^{185}		% 37.07 (WhiJ48) Δ -43.73 (MTW) σ_c 110 (GoldmDT64)			
Re^{186}	88.9 h (PortF56) 92.8 h (GooLJ47) 91 h (CorkJ48b) 90 h (SinK39)	☢ β^- 95%, EC 5% (MalyL64) others (PortF56, JohnM56, MetF51) no β^+, lim 10^{-5}% (MetF51) Δ -41.9 (MTW)	A n-capt (KurtI35) n-capt, excit (SinK39) chem, n-capt, excit (FajK40a) mass spect (HessD47)	β^- 1.07 max e^- 0.063, 0.125 γ W X-rays, Os X-rays, 0.137 (9%), 0.632 (0.032%), 0.768 (0.035%)	Re^{185}(n, γ) (KurtI35, SinK39, FajK40a, SerL47b)
Re$^{186?}$	1 h (HaldB57)	☢ (HaldB57)	D chem (HaldB57)		protons on Re, W (HaldB57)
Re^{187}	4.3 x 10^{10} y genet (HirtB63) 1.2 x 10^{11} y sp act (WolfC62) others (HerrW58, WatD62a, HinH54, SutA54, DixD54a, NalS48, SugaN48)	☢ β^- (NalS48) % 62.93 (WhiJ48) Δ -41.14 (MTW) σ_c 70 (to Re^{188}) 1.3 (to Re^{188m}) (GoldmDT64)	A chem (NalS48)	β^- 0.003 max (in about 1/3 of the decays the electron goes into a stable atomic orbit)	
Re^{188}	16.7 h (FlaA53, AjzF56, DzhB54) 16.9 h (LindnM51a) 18.9 h (GooLJ47) others (PoolM37, DoyW63a)	☢ β^- (SinK39) Δ -38.79 (MTW) σ_c <2 (GoldmDT64)	A chem, n-capt (AmaE35) n-capt, excit (SinK39) chem, n-capt, excit (FajK40) mass spect (HessD47) daughter W^{188} (LindnM51a, LindnM51, RoyJ62) daughter Re^{188m} (HerrW52)	β^- 2.12 max e^- 0.081, 0.143 γ Os X-rays, 0.155 (10%), 0.478 (0.6%), 0.633 (0.9%), 0.829 (0.3%), 0.932 (0.4%), other weak γ's to 2.0	Re^{187}(n, γ) (KurtI35, AmaE35, PoolM37, SinK39, FajK40a, SerL47b)
Re^{188m}	18.7 m (TakaK64, FlaA53) others (ButeF50, MihJ53b)	☢ IT (MihJ53b) Δ -38.62 (LHP, MTW)	A n-capt, sep isotopes (MihJ53b) chem, genet (HerrW52) parent Re^{188} (HerrW52)	γ Re X-rays, 0.092 (5%), 0.106 (10%) e^- 0.004, 0.013, 0.021, 0.034, 0.051, 0.061, 0.080, 0.093 daughter radiations from Re^{188}	Re^{187}(n, γ) (MihJ53b)
Re^{189}	24.3 h (BliP65) 23 h (CrasB63)	☢ β^- (CrasB63) Δ -37.8 (MTW)	A chem, excit, cross bomb (CrasB63) genet energy levels (CrasB63, ResD61) daughter W^{189} (FleJ63, KauP65a)	β^- 1.00 max e^- 0.023, 0.028, 0.057, 0.074, 0.112, 0.143, others between 0 and 0.25 γ Os X-rays, 0.150 (4%, doublet), 0.187 (3%, doublet), 0.218 (10%, doublet), 0.245 (4%)	W^{186}(α, p) (CrasB63) Os^{189}(n, p) + Os^{190}(n, pn) (CrasB63) Os^{192}(d, αn) (FleJ63)
Re^{189}	140 d (BliP65) 150 d (LindnM51a)	☢ β^- (LindnM51a, TurS51) β^-, IT (?) (BliP65)	F chem (LindnM51a, TurS51) chem, genet energy levels (BliP65) activity assigned to Re^{184m} (CrasB63, JohnN63)	γ 0.211, 0.57, 0.67	W^{186}(α, p) (BliP65, TurS51)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12} = 0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{75}$Re$^{[189?]}$	≥5 y (LindnM51a)	☢ β^- (LindnM51a)	F chem (LindnM51a) activity not observed (SmiRR56a)	β^- 0.75 max ac[illegible] not observed	neutrons on Re (LindnM51a)
Re^{190}	2.8 m (AteA55) others (BaroG62)	☢ β^- (AteA55) Δ −35.4 (MTW)	B chem, genet energy levels, cross bomb (AteA55)	β^- 1.6 max γ Os X-rays, 0.191 (↑ 10), 0.392 (↑ 10), 0.57 (↑ 10), 0.83 (↑ 3)	Os^{192}(d, α), Os^{190}(n, p) (AteA55)
Re^{190m}	2.8 h (FleJ64, BaroG62)	☢ [IT] (FleJ64, BaroG62)	B chem, cross bomb, sep isotopes (FleJ64, BaroG62)	β^- 1.6 max γ [Os] X-rays, 0.12, 0.19, 0.23, 0.38 (complex), 0.56 (complex), 0.82 (these are probably daughter radiations of 2.8 m Re^{190} according to FleJ64)	Os^{192}(d, α), Os^{190}(n, p), Ir^{193}(n, α) (FleJ64, BaroG62)
Re$^{[191]}$	9.8 m (AteA53c)	☢ β^- (AteA53c) Δ −34.6 (NDS, MTW)	D chem (AteA53c) excit (AteA55) decay charac (CrasB63)	β^- 1.8 max	[Os^{192}(n, np)] (AteA53c)
Re^{192}	6 s (BlacJe65a)	☢ β^- (BlacJe65a)	C sep isotopes, genet energy levels (BlacJe65a)	β^- 2.5 max γ 0.20, 0.29, 0.37, 0.48, 0.57	Os^{192}(n, p) (BlacJe65a)
$_{76}$Os^{181}	23 m (FosJ58)	☢ [EC] (FosJ58) Δ −44 (NDS, MTW)	B chem, excit, sep isotopes, genet (FosJ58) activity not observed (SurY60) parent Re^{181} (FosJ58)	γ [Re X-rays], others e^- 0.093, 0.101 daughter radiations from Re^{181}	Re^{185}(p, 5n) (FosJ58)
Os^{181}	2.7 h (SurY60)	☢ [EC) (SurY60)	E chem, genet (SurY60) parent Re^{181} (SurY60)	γ Re X-rays, 0.23 daughter radiations from Re^{181}	protons on Au (SurY60)
Os^{182}	21.9 h (FosJ58) 21.1 h (NewJ60a) 20 h (GranG63) others (StovB50)	☢ EC, no β^+ (StovB50) Δ −44 (NDS, MTW)	A chem, genet (StovB50) chem, excit, sep isotopes (NewJ60a) parent 12.7 h Re^{182} (StovB50, FosJ58) daughter Ir^{182} (DiaR61)	γ Re X-rays, 0.180 (↑ 7), 0.263 (↑ 1.4), 0.510 (↑ 10) e^- 0.015, 0.025, 0.043, 0.052, 0.108, 0.438 daughter radiations from 12.7 h Re^{182}	Re^{185}(p, 4n) (StovB50) W^{182}(α, 4n) (NewJ60a)
Os^{183}	12.0 h (NewJ60a, StovB50) 15.4 h (FosJ58) others (GranG63, SurY60)	☢ EC (StovB50) Δ −43 (NDS, MTW)	A chem, genet (StovB50) parent Re^{183} (StovB50) daughter Ir^{183} (DiaR61, LavA61)	γ Re L X-rays, Re K X-rays (170%), 0.114 (27%), 0.168 (10%), 0.236 (5%), 0.382 (90%), 0.48 (9%, complex), 0.86 (5%, complex), 1.44 (1%) e^- 0.043, 0.102, many others between 0 and 1.4, all weak	Re^{185}(p, 3n) (FosJ58, StovB50) alphas on W (NewJ60a) daughter Ir^{183} from Lu^{175}(C^{12}, 4n) (DiaR61)
Os^{183m}	9.9 h (NewJ60a) 10 h (FosJ58)	☢ EC ≈54%, IT ≈46% (NewJ60a, NewJ60b) Δ −43 (NDS, MTW)	A chem, excit, sep isotopes (FosJ58, NewJ60a) genet (DiaR61) daughter Ir^{183} (DiaR61)	γ Os X-rays, 1.035 (6%), 1.105 (48%, complex) e^- 0.055, 0.096, 0.158, 0.168 daughter radiations from Os^{183}	Re^{185}(p, 3n) (FosJ58) alphas on W (NewJ60a) daughter Ir^{183} from Lu^{175}(C^{12}, 4n) (DiaR61)
Os^{184}		% 0.018 (NierA37) Δ −44.0 (MTW) σ_c <200 GoldmDT64)			
Os^{185}	93.6 d (JohnM57) others (FosJ58, GooLJ47, KatziL48, TurS51, SurY60, GranG63)	☢ EC (MillM51a) no β^+, lim 4 x 10^{-4}% (MaliS58) Δ −42.74 (MTW)	A chem, cross bomb (GooLJ47, KatziL48) chem, genet energy levels (MartyN57)	γ Re X-rays, 0.646 (80%), 0.875 (14%, complex) e^- 0.059, 0.091, 0.574, 0.634	Re^{185}(d, 2n) (GooLJ47, ChuT50) Os^{184}(n, γ) (KatziL48) Re^{185}(p, n) (FosJ58, StovB50)
Os^{186}		% 1.59 (NierA37) Δ −43.0 (MTW)			
Os^{187}		% 1.64 (NierA37) Δ −41.14 (MTW)			
Os^{187m}	39 h (GreeG56) 35 h (ChuT50)	☢ (ChuT50)	G chem (ChuT50) activity not observed (NewJ60a, MerE63)		

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$_{76}$Os^{188}		% 13.3 (NierA37) Δ −40.91 (MTW)			
Os$^{?}$	26 d (GreeG56)	☢ (GreeG56)	F chem (GreeG56)	γ X-rays	N^{14} on Os (GreeG56)
Os^{189}		% 16.1 (NierA37) Δ −38.8 (MTW) σ_c 0.008 (to Os^{190m}) (GoldmDT64)			
Os^{189m}	5.7 h (SchaG58) others (ChuT50, GreeG56)	☢ IT (SchaG58) Δ −38.8 (LHP, MTW)	A chem (ChuT50, GreeG56) chem, genet (SchaG58) genet energy levels (NewJ60c, CrasB63) daughter Ir^{189} (SchaG58)	γ Os L X-rays e$^-$ 0.019, 0.028	daughter Ir^{189} (SchaG58)
Os^{190}		% 26.4 (NierA37) Δ −38.5 (MTW) σ_c 3.9 (to Os^{191}) 8.6 (to Os^{191m}) (GoldmDT64)			
Os^{190m}	9.9 m (SchaG58) others (ChuT50, AteA55c, MalyT61, MangS62)	☢ IT (SchaG58, AteA55c) Δ −36.8 (LHP, MTW)	A chem, genet (ChuT50, AteA55c) genet energy levels (SchaG58, ResD61) daughter Ir^{190m_2} (ChuT50, AteA55c)	γ Os X-rays, 0.187 (70%), 0.361 (94%), 0.502 (98%), 0.616 (99%) e$^-$ 0.026, 0.036, 0.113, 0.175	daughter Ir^{190m_2} (ChuT50, AteA55c, SchaG58)
Os^{191}	15.0 d (KatziL48) 16.0 d (ChuT50) 14.6 d (NabS58)	☢ β$^-$ (SeaG41b) Δ −36.4 (MTW)	A n-capt (ZinE40) chem, n-capt (SeaG41b) chem, excit (SwanJ52) daughter Os^{191m} (SwanJ52) parent Ir^{191m} (NauR54a, CamE56)	β$^-$ 0.143 max e$^-$ 0.030, 0.042, 0.053, 0.116, 0.127 γ Ir X-rays, 0.129 (25%) daughter radiations from Ir^{191m} included in above listing	Os^{190}(n, γ) (SeaG41b, ZinE40, SerL47b, SwanJ52)
Os^{191m}	13.0 h (PlaZ63) 14 h (SwanJ52)	☢ IT, no β$^-$ (lim 5%) (SwanJ52) Δ −36.3 (LHP, MTW)	A chem, genet (SwanJ52) parent Os^{191} (SwanJ52)	γ Os L X-rays e$^-$ 0.062, 0.072 daughter radiations from Os^{191}	Os(n, γ) (SwanJ52)
Os^{192}	t$_{1/2}$ (ββ) >10^{14} y sp act (FremJ52)	% 41.0 (NierA37a) Δ −35.9 (MTW) σ_c 1.6 (GoldmDT64)			
Os^{193}	31.5 h (NabS58) 30.6 h (ChuT50) others (GooLJ47, SeaG41b, ZinE40)	☢ β$^-$ (SeaG41b) Δ −33.32 (MTW) σ_c 200 (GoldmDT64)	A n-capt (KurtI35, ZinE40) chem, n-capt (SeaG41b) chem, excit (SwanJ52)	β$^-$ 1.13 max e$^-$ 0.060, 0.070 γ Ir X-rays, 0.139 (3%), 0.28 (2.1%, complex), 0.322 (1.4%), 0.38 (2.0%, complex), 0.460 (3.9%), 0.558 (2.1%)	Os^{192}(n, γ) (KurtI35, ZinE40, SeaG41b, SerL47b)
Os^{194}	6.0 y (JohnN65b) 5.8 y (WilliDC64) others (LindnM51a)	☢ β$^-$ (WilliDC64) Δ −32.39 (MTW)	A chem, genet (LindnM50) chem, genet, n-capt (WilliDC64) parent Ir^{194} (LindnM50, LindnM51a, WilliDC64)	β$^-$ 0.053 max e$^-$ [0.029, 0.040] γ Ir X-rays, 0.043 (10%), 0.078 (0.03%) daughter radiations from Ir^{194}	Os^{192}(n, γ)Os^{193}(n, γ) WilliDC64, LindnM50, LindnM51a)
Os^{195}	6.5 m (BaroG57, ReyP57)	☢ β$^-$ (BaroG57, ReyP57) Δ −30 (MTW)	B chem, genet (BaroG57, ReyP57) parent Ir^{195} (BaroG57, ReyP57)	β$^-$ 2 max	Pt^{198}(n, α) (BaroG57, ReyP57)
$_{77}$Ir^{182}	15 m (DiaR61)	☢ EC, [β$^+$] (DiaR61) Δ −39 (NDS, MTW)	A chem, cross bomb, genet (DiaR61) parent Os^{182} (DiaR61)	γ Os X-rays, 0.133, 0.278, 0.510, others to ≈4	Lu^{175}(C^{12}, 5n), Tm^{169}(O^{16}, 3n) (DiaR61)
Ir^{183}	0.9 h (DiaR61) 1.0 h (LavA61) others (SurY60)	☢ EC (DiaR61, LavA61)	A chem, genet (DiaR61, LavA61) parent Os^{183} (DiaR61, LavA61) parent Os^{183m} (DiaR61)	γ Os X-rays, 0.24 daughter radiations from Os^{183m}, Os^{183}	Lu^{175}(C^{12}, 4n) (DiaR61)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{77}$Ir^{184}	3.2 h (DiaR61) 3.1 h (BaranV60)	☢ EC, β^+ (DiaR61) Δ −40 (NDS, MTW)	B chem, decay charac (BaranV60) chem, excit, decay charac (DiaR61) daughter 42 m Pt^{184} (QaiS65)	γ Os X-rays, 0.125 (↑ 100), 0.267 (↑ 200), 0.392 (↑ 90), 0.51 ($\gamma^{\pm}$?), 0.83, 0.96, 1.09, others to 4.3	Lu^{175}(C^{12}, 3n) (DiaR61)
Ir^{185}	14 h (EmeG63) 15 h (DiaR58)	☢ EC (DiaR58) Δ −40 (NDS, MTW)	B chem, excit (DiaR58) sep isotopes (HarmB62) daughter Pt^{185} (QaiS65)	γ Os X-rays, 0.101, 0.254, others e^- 0.024, 0.034, 0.047, 0.085, 0.180	Re^{185}(α, 4n) (DiaR58, EmeG63) Os^{186}(p, 2n) (HarmB62)
Ir^{186}	15.8 h (EmeG63) 14 h (SmiW55) 16 h (DiaR58) others (MalyT60, KryL61)	☢ EC 97%, β^+ 3% (EmeG63) Δ −39.1 (MTW)	A chem, excit (DiaR58) genet energy levels (EmeG63) daughter Pt^{186} (SmiW55, QaiS65)	γ Os X-rays, 0.137 (45%), 0.297 (74%), 0.434 (35%), 0.511 (6%, $\gamma^{\pm}$), 0.64 (9%, complex), 0.77 (8%, complex), 1.60–1.75 (4%, complex), many others between 0 and 3.0 β^+ 1.94 max e^- 0.063, 0.125, 0.135, 0.226	Re^{185}(α, 3n) (DiaR58, EmeG63)
Ir^{186}	1.7 h (MalyT63) 2.0 h (BoncN62, GranG63)	☢ β^+, EC (BoncN62, GranG63)	B chem (BoncN62, MalyT63) chem, excit (GranG63) not daughter Pt^{186} (QaiS65)	γ Os X-rays, 0.137, 0.295, 0.511 ($\gamma^{\pm}$), 0.630, 0.77, 0.99, others β^+ 2.6 max e^- 0.063, 0.125	Ir^{191}(p, p5n) (GranG63)
Ir^{187}	10.5 h (EmeG63) others (DiaR58, MalyT60, KryL61)	☢ EC (DiaR58) Δ −40 (MTW)	B chem, excit (DiaR58) daughter Pt^{187} (BaranV60)	γ Os X-rays, 0.18 (↑ 45), 0.31 (↑ 14), 0.41 (↑ 100), 0.50 (↑ 35), 0.61 (↑ 45), 0.90 (↑ 40), 0.98 (↑ 50), all γ rays complex, many others e^- 0.007, 0.013, 0.053, 0.063, 0.073, 0.104, many others between 0 and 1.1	Re^{185}(α, 2n) (DiaR58, EmeG63)
Ir^{188}	41.5 h (ChuT50) others (SmiW55, NauR54, GranG63, KryL61, MalyT60)	☢ EC 99+%, β^+ ≈0.3% (ChuT50) Δ −38.08 (MTW)	A chem, excit, sep isotopes (ChuT50) genet energy levels (GrahR62, MarkI63) daughter Pt^{188} (NauR54, SmiW55)	γ Os X-rays, 0.155 (34%), 0.478 (16%), 0.633 (29%, doublet), 0.829 (7%), 1.210 (7%), 1.717 (4%), 2.08 (16%, complex), 2.217 (13%), many others between 0 and 2.7 β^+ 1.66 max e^- 0.081, 0.143, many others between 0 and 2.7	alphas on Re (ChuT50, WarnL62, YamaT63) Os^{189}(p, 2n) (HarmB64) deuterons on Os (ChuT50)
Ir^{189}	13.3 d (GranG63, LewisH64) others (ChuT50, SmiW55, MalyT60, KryL61)	☢ EC (SmiW55) Δ −38 (MTW)	A chem, genet (SmiW55) daughter Pt^{189} (SmiW55) parent Os^{189m} (SchaG58)	γ Os X-rays, 0.245 (18%) e^- 0.023, 0.046, 0.058, 0.067, 0.171, many others between 0 and 0.27	Ir^{191}(p, 3n) Pt^{189}(EC) (GranG63, LewisH64) Re^{187}(α, 2n) (DiaR58) Os^{190}(p, 2n) (HarmB62)
Ir^{190}	11 d (GranG63, AteA55c) 10.7 d (GooLJ47) 12.3 d (KaneW60) 12.6 d (ChuT50)	☢ EC (AteA55c) no β^+, lim 0.002% (KaneW60) Δ −36.5 (MTW)	A chem, excit, cross bomb (GooLJ47, AteA55c) genet energy levels (KaneW60, ResD61)	γ Os X-rays, 0.187 (51%), 0.37 (39%, complex), 0.40 (39%, complex), 0.518 (39%), 0.56 (72%, complex), 0.604 (47%), others to 1.7 e^- 0.113, 0.175, others to 1.7	Re^{187}(α, n) (ChuT50) Os^{189}(d, n) (GooLJ47) Os^{190}(p, n) (HarmB64)
Ir^{190m_1}	1.2 h (HarmB64)	☢ IT (HarmB64) Δ −36.5 (LHP, MTW)	B chem, sep isotopes, excit (HarmB64)	γ Ir L X-rays e^- 0.015, 0.024 daughter radiations from Ir^{190}	Os^{190}(p, n) (HarmB64)
Ir^{190m_2}	3.2 h (ChuT50) 3.0 h (GranG63)	☢ EC 94%, IT 6% (HarmB64) EC 90%, β^+ 10% (AteA55c) Δ −36.3 (LHP, MTW)	A chem, excit, sep isotopes (ChuT50) chem, cross bomb (AteA55c) genet energy levels (HarmB64) parent Os^{190m} (ChuT50, AteA55c)	γ Os X-rays, Ir X-rays, 0.187 (66%), 0.361 (88%), 0.502 (92%), 0.616 (93%) e^- 0.026, 0.036, 0.113, 0.175 daughter radiations from Ir^{190m_1}, Ir^{190} daughter radiations from Os^{190m} included in above listing	Re^{187}(α, n) (ChuT50) deuterons on Os (ChuT50) Os^{190}(p, n) (HarmB64)
Ir^{191}		% 38.5 (SamM36a) Δ −36.7 (MTW) σ_c 750 (to Ir^{192}) 250 (to Ir^{192m_1}) 0.3 (to Ir^{192m_2}) (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensitie.	Principal means of production
$_{77}\mathrm{Ir}^{191m}$	4.9 s (FiscV55, CamE56) 4.5 s (CloJ58) others (NauR54a, MihJ54a)	☢ IT (NauR54a) Δ −36.5 (LHP, MTW)	A chem, genet (NauR54a, CamE56) daughter Os^{191} (NauR54a, CamE56)	γ Ir X-rays, 0.129 (25%) e^- 0.030, 0.042, 0.053, 0.116, 0.127	daughter Os^{191} (NauR54a, CamE56) Os^{192}(p, 2n) (CloJ58)
Ir^{192}	74.2 d (AlliJ60) 74.4 d (KasJ51) others (WyaE61, HarbG63, SinW51, ChuT50)	☢ β^- 95.5%, EC 4.5% (BashA56) β^- 96.5%, EC 3.5% (BagL55) β^+ 1.5 x 10^{-5}% (AntoS60) Δ −34.7 (MTW) σ_c 700 (to Ir^{193m}) (GoldmDT64)	A n-capt (AmaE36) mass spect (RalW46) chem (WilkG48) daughter Ir^{192m_1}, daughter Ir^{192m_2} (SchaG59)	β^- 0.67 max e^- 0.217, 0.230, 0.239, 0.390 γ Os X-rays, Pt X-rays, 0.296 (29%), 0.308 (30%), 0.317 (81%), 0.468 (49%), 0.589 (4%), 0.604 (9%), 0.612 (6%)	Ir^{191}(n, γ) (AmaE36, MMilE37, JaeR38, SerL47b) Os^{192}(d, 2n) (GooLJ47, ChuT50)
Ir^{192m_1}	1.42 m (HoleN48b, MizJ54) 1.45 m (WebG53) others (SchaG61, MMilE37)	☢ IT 99+%, β^- 0.017% (SchaG61, SchaG59) Δ −34.7 (LHP, MTW, NDS)	A n-capt (MMilE37) resonance neutron activation (GoldhM47) parent Ir^{192} (SchaG59) not daughter Ir^{192m_2} (SchaG59)	γ Ir L X-rays, 0.058 (0.005%), 0.317 (0.008%), 0.612 (0.003%) e^- 0.046, 0.056 β^- 1.5 max	Ir^{191}(n, γ) (MMilE37, GoldhM47, SerL47b) Os^{192}(d, 2n) (GooLJ47) ChuT50)
Ir^{192m_2}	>5 y (SchaG59)	☢ IT (SchaG59) Δ −34.6 (LHP, MTW, NDS)	B genet, n-capt (SchaG59) parent Ir^{192} (SchaG59) not parent Ir^{192m_1} (SchaG59)	γ Ir K X-rays (weak), Ir L X-rays e^- 0.149, 0.158 daughter radiations from Ir^{192}	Ir^{191}(n, γ) (SchaG59)
$\underline{\mathrm{Ir}^{193}}$		% 61.5 (SamM36a) Δ −34.45 (MTW) σ_c 110 (GoldmDT64)			
Ir^{193m}	11.9 d (BoeF57)	☢ IT (BoeF57) Δ −34.37 (LHP, MTW)	B chem, n-capt (BoeF57)	γ Ir L X-rays e^- 0.069, 0.078	Ir^{191}(n, γ)Ir^{192}(n, γ) (BoeF57)
Ir^{194}	17.4 h (PeiM64) 19.0 h (GooLJ47) others (WitC41, AmaE35, MMilE37, SerL47b)	☢ β^- (MMilE37) Δ −32.49 (MTW)	A n-capt (AmaE35) mass spect (RalW46) chem (WilkG48) daughter Os^{194} (LindnM50, LindnM51a, WilliDC64)	β^- 2.24 max γ 0.328 (10%), 0.64 (1.0%, doublet), 0.939 (0.4%), 1.16 (0.8%, complex), 1.48 (0.6%, complex), 1.7 (0.2%, complex), many others	Ir^{193}(n, γ) (AmaE35, PoolM37, SerL47b, MMilE37, JaeR38) daughter Os^{194} (PeiM64)
Ir^{194m}	47 s (HennH60, HennH60a)	☢ β^-, IT (HennH60, HennH60a)	G n-capt, decay charac (HennH60, HennH60a, HennH61) activity not observed (SchaG61) activity produced by thermal neutrons on Ir, but not with enriched Ir^{193} (FetP62a)	β^- 2.3 max (HennH60a) γ 0.13, 0.32, 0.63 (HennH60a)	neutrons on Ir (HennH60, HennH60a)
Ir^{195}	4.2 h (ClafA62) 2.3 h (ButeF54) 2.7 h (ChrisD52)	☢ β^- (ChrisD52) Δ −31.8 (MTW)	B chem, excit (ChrisD52, ButeF54, HomS61) sep isotopes (ClafA62) daughter Os^{195} (BaroG57, ReyP57)	β^- 1.0 max γ Pt X-rays, 0.10, 0.13, 0.33, 0.37, 0.43, 0.66	Pt^{195}(n, p) (ButeF54) Pt^{196}(γ, p) (ChrisD52, HomS61) Os^{192}(α, p) (ClafA62)
Ir^{196}	120 m (BisW65)	☢ β^- (BisW65) Δ −29.23 (BisW65, MTW)	B chem, genet energy levels, sep isotopes (BisW65)	β^- 0.95 max γ 0.100 (33%), 0.356 (94%), 0.39 (95%), 0.44 (95%), 0.522 (99%), 0.65 (100%)	Pt^{198}(d, α) (BisW65)
Ir^{196}	9.7 d (ButeF54)	☢ β^- (ButeF54)	G chem, cross bomb (ButeF54) activity assigned to Ir^{189} + Ir^{190} (GardD57); not produced by Pt^{194}(d, α) (GardD57)		
Ir^{197}	7 m (ChrisD52, ButeF54, HomS61)	☢ β^- (ButeF54) Δ −28.4 (MTW)	D chem, excit (ChrisD52) chem, cross bomb (ButeF54)	β^- 2.0 max γ 0.50	Pt^{198}(n, pn) (ButeF54) Pt^{198}(γ, p) (ChrisD52, HomS61)
Ir^{198}	50 s (ButeF54)	☢ β^- (ButeF54) Δ −25.5 (MTW)	C excit, cross bomb (ButeF54)	β^- 3.6 max γ 0.78	Pt^{198}(n, p) (ButeF54)

Isotope Z A	Half-life		Type of decay (☢); % abundance; Mass excess (△≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns		Class; Identification; Genetic relationships		Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{78}$Pt^{173}	short (SiiA66)	☢	α (SiiA66)	F	cross bomb, excit (SiiA66)	α	6.19	O^{16} on Yb, Ne^{20} on Er (SiiA66)
Pt^{174}	0.7 s (SiiA66)	☢	α 80%, [EC+β$^+$] 20% (SiiA66)	B	cross bomb, excit (SiiA66)	α	6.03	O^{16} on Yb, Ne^{20} on Er (SiiA66)
Pt^{175}	2.1 s (SiiA66)	☢	α (SiiA66)	B	cross bomb, excit (SiiA66)	α	5.95	O^{16} on Yb, Ne^{20} on Er (SiiA66)
Pt^{176}	6.0 s (SiiA66)	☢	α 1.4%, [EC+β$^+$] 98.6% (SiiA66)	B	cross bomb, excit (SiiA66)	α	5.74	O^{16} on Yb, Ne^{20} on Er (SiiA66)
Pt^{177}	6.6 s (SiiA66)	☢	α 0.3%, [EC+β$^+$] 99+% (SiiA66)	B	cross bomb, excit (SiiA66)	α	5.51	O^{16} on Yb, Ne^{20} on Er (SiiA66)
Pt^{178}	21 s (SiiA66)	☢	α 1.3%, [EC+β$^+$] 98.7% (SiiA66)	B	cross bomb, excit (SiiA66)	α	5.44	O^{16} on Yb, Ne^{20} on Er (SiiA66)
Pt^{179}	33 s (SiiA66)	☢	α 0.1%, [EC+β$^+$] 99+% (SiiA66)	B	cross bomb, excit (SiiA66)	α	5.15	O^{16} on Yb, Ne^{20} on Er (SiiA66)
Pt^{180}	50 s (SiiA66)	☢	α 0.3%, [EC+β$^+$] 99+% (SiiA66)	B	cross bomb, excit (SiiA66)	α	5.14	O^{16} on Yb, Ne^{20} on Er (SiiA66)
Pt^{181}	51 s (SiiA66)	☢	α 0.0006%, [EC+β$^+$] 99+% (SiiA66)	B	cross bomb, excit (SiiA66)	α	5.02	O^{16} on Yb, Ne^{20} on Er (SiiA66)
Pt^{182}	3.0 m (SiiA66) 2.5 m (GraeG63)	☢ △	α 0.02%, [EC+β$^+$] 99+% (GraeG63, SiiA66) −36 (NDS, MTW)	B	chem, decay charac (GraeG63) cross bomb, excit (SiiA66)	α	4.84 daughter radiations from Ir^{182}	O^{16} on Yb, Ne^{20} on Er (SiiA66) protons on Ir (GraeG63)
Pt^{183}	6.5 m (GraeG63) 7 m (SiiA66)	☢	α 0.001%, [EC+β$^+$] 99+% (GraeG63, SiiA66)	B	chem, decay charac (GraeG63) cross bomb, excit (SiiA66)	α	4.73	O^{16} on Yb, Ne^{20} on Er (SiiA66) protons on Ir (GraeG63)
Pt^{184}	20 m (GraeG63) 16 m (SiiA66)	☢	α 0.0015%, [EC+β$^+$] 99+% (GraeG63, SiiA66)	B	chem, decay charac (GraeG63) cross bomb, excit (SiiA66)	α	4.50	O^{16} on Yb, Ne^{20} on Er (SiiA66) Ir^{193}(p, 10n) (GraeG63)
Pr^{184}	42 m (QaiS65)	☢	EC (QaiS65)	D	chem, genet (QaiS65) parent Ir^{184} (QaiS65)	γ	[Ir X-rays], 0.68, 1.72, 1.85 daughter radiations from Ir^{184}	N^{14} on Ta (QaiS65)
Pt^{185}	1.2 h (AlboG60) 1.0 h (QaiS65)	☢	[EC] (AlboG60)	C	genet (AlboG60) chem, genet (QaiS65) daughter 7 m Au^{185} (AlboG60) parent Ir^{185} (QaiS65)	γ	[Ir X-rays], 0.035, 0.63, 1.56 daughter radiations from Ir^{185}	descendant Hg^{185} (AlboG60) N^{14} on Ta (QaiS65)
Pt^{186}	3.0 h (GranG63) 2.9 h (AlboG60) 2.8 h (QaiS65) 2.5 h (SmiW55) 2.0 h (α) (GraeG63)	☢	EC (SmiW55, AlboG60) α 1.4 x 10^{-4}% (GraeG63)	B	chem, genet (SmiW55, AlboG60) chem, excit (GranG63) parent 16 h Ir^{186} (SmiW55, QaiS65) not parent 1.7 h Ir^{186} (QaiS65) daughter Au^{186} (SmiW55)	γ α	Ir X-rays, 0.67 4.23 daughter radiations from 16 h Ir^{186}	protons on Ir (GranG63)
Pt^{187}	2.0 h (BaranV60) 2.1 h (QaiS65) 3.1 h (GranG63) 2.2 h (AlboG60) others (KryL61, MalyT60)	☢	EC (BaranV60)	B	chem, genet (BaranV60) chem, excit (GranG63) parent Ir^{187} (BaranV60) daughter Au^{187} (AlboG60)	γ	Ir X-rays, 0.11 (?), 0.18 (?), 2.0 daughter radiations from Ir^{187}	protons on Ir (GranG63)
Pt^{188}	10.2 d (GraeG63) 10.0 d (SmiW55) others (NauR54, KarrM63, GranG63)	☢ △	EC (NauR54) α 3 x 10^{-5}% (GraeG63) α 5 x 10^{-5}% (KarrM63) −37.6 −MTW)	A	chem, genet (NauR54, SmiW55) parent Ir^{188} (NauR54, SmiW55) daughter Au^{188} (SmiW55)	γ e$^-$ α	Ir X-rays, 0.140 (! 22), 0.19 (! 100, complex), 0.38 (! 15), 0.42 (! 7) 0.042, 0.111, 0.119, others between 0 and 0.4 daughter radiations from Ir^{188} 3.93	Ir^{191}(p, 4n) (GranG63)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{78}Pt^{189}$	10.9 h (LewisH64) 10.5 h (GrigE62) 11.1 h (AndeG61) others (KryL61, GranG63, PofN60, AlboG60, SmiW55, QaiS65)	☢ EC (SmiW55, AlboG60) Δ -37 (MTW)	A chem, excit, genet (SmiW55) chem, excit (GranG63) parent Ir^{189} (SmiW55) daughter Au^{189} (SmiW55, ChacK57) descendant Hg^{189} (AndeG61, PofN60, AlboG60)	γ Ir X-rays, 0.094 (↑ 120), 0.114 (↑ 61), 0.141 (↑ 124), 0.187 (↑ 137), 0.243 (↑ 100), 0.31 (↑ 96, complex), 0.404 (↑ 32), 0.56 (↑ 230, complex), 0.61 (↑ 180, complex), 0.722 (↑ 156), 0.80 (↑ 27, complex) e^- 0.037, 0.058, 0.068, 0.082, 0.092, 0.168, 0.231, 0.241, many others between 0 and 0.8 daughter radiations from Ir^{189}	Ir^{191}(p, 3n) (GranG63)
Pt^{190}	6.9×10^{11} y sp act (MacfR61a) 5.4×10^{11} y sp act (GraeG63) others (PetrK61, GraeG61, PorsW56, PorsW54)	☢ α (PorsW54) % 0.0127 (WhiF56) Δ -37.3 (MTW) σ_c ≈150 (GoldmDT64)	A decay charac (PorsW56) chem, sep isotopes (MacfR61a)	α 3.18	
Pt^{191}	3.00 d (WilkG49a) others (CorkJ54a, SwanJ53a, SmiW55, LindsJ62, KryL61, GranG63)	☢ EC (WilkG48) Δ -36 (MTW)	A chem, excit (WilkG48) genet energy levels (GillL54) daughter Au^{191} (SmiW55)	γ Ir X-rays, 0.0[illegible] (1%), 0.129 (2%), 0.175 (1%, complex), 0.269 (1%), 0.36 (5%, complex), 0.410 (3%), 0.457 (1%), 0.539 (9%), 0.624 (1%) e^- 0.020, 0.053, 0.069, 0.080, others between 0 and 0.6	protons on Ir (GranG63, HarmB62) Ir^{191}(d, 2n) (WilkG49a)
Pt^{192}	≈10^{15} y sp act (PorsW56) >10^{14} y sp act (GraeG63)	☢ α (PorsW56) % 0.78 (WhiF56) Δ -36.2 (MTW) σ_c <14 (to Pt^{193}) 2 (to Pt^{193m}) (GoldmDT64)	E decay charac (PorsW56)	α 2.6 ?	
Pt^{193}	<500 y yield (NauR56) >74 d, or <1 h (no activity observed (SwanJ53a)	☢ EC (L/K>1000), no β^-, no β^+ (NauR56) Δ -34.41 (MTW)	B n-capt, chem (NauR56)	γ Ir L X-rays	Pt^{192}(n, γ) (NauR56)
Pt^{193m}	4.3 d (WilkG49a) 3.4 d (CorkJ54a) 4.4 d (EwaG57) 4.5 d (SwanJ53a) 3.5 d (BrunnJ55)	☢ IT (SwanJ53a) Δ -34.26 (LHP, MTW)	B chem, excit (WilkG48) daughter Au^{193m} (0.03%) (BrunnJ55) daughter Au^{193} (WilkG49a)	γ Pt X-rays e^- 0.01, 0.057, 0.124, 0.133	Ir^{193}(d, 2n), Pt^{192}(n, γ) (WilkG49a)
Pt^{194}		% 32.9 (WhiF56) Δ -34.72 (MTW) σ_c 1.1 (to Pt^{195}) 0.09 (to Pt^{195m}) (GoldmDT64)			
Pt^{195}		% 33.8 (WhiF56) Δ -32.78 (MTW) σ_c 27 (GoldmDT64)			
Pt^{195m}	4.1 d (BresM60) others (HoleN48b, DShaA52, HaldB52, MMilE37, MalyT60)	☢ IT (DShaA52) Δ -32.52 (LHP, MTW)	A chem (MMilE37) chem, genet (?) (DShaA52) genet energy levels (CorkJ54a, BernsE55)	γ Pt X-rays, 0.099 (11%), 0.129 (1%) e^- 0.018, 0.028, 0.051, 0.085, 0.116, 0.126	Pt^{194}(n, γ) (MandeC48d, HaldB52, DShaA52, MMilE37, PoolM37, SerL47b, HubeO51) Pt^{194}(d, p) (KriR41c)
Pt^{196}		% 25.2 (WhiF56) Δ -32.63 (MTW) σ_c 0.9 (to Pt^{197}) 0.05 (to Pt^{197m}) (GoldmDT64)			
Pt^{197}	18 h (MMilE37) 20.0 h (BresM60) 17.4 h (CorkJ52a)	☢ β^- (MMilE37) Δ -30.42 (MTW)	A chem (CorkJ36) chem, excit (MMilE37)	β^- 0.670 max e^- 0.063, 0.074, 0.110 γ Au X-rays, 0.077 (20%), 0.191 (6%)	Pt^{196}(n, γ) (MMilE37, SherrR41, SerL47b, HaldB52)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{78}$Pt^{197m}	78 m (HoleN48b) 80 m (SherrR41, MangS62) 88 m (ChrisD52)	☢ IT (HoleN48b) β^- 3% (HavA65) Δ -30.02 (LHP, MTW)	A chem (SherrR41) chem, excit, cross bomb (ChrisD52) genet, genet energy levels (HavA65) parent Au^{197m} (PraK64, HavA65)	γ Pt X-rays, 0.279 (2.6%), 0.346 (13%) e^- 0.040, 0.050, 0.268, 0.332 β^- 0.737 max (3%) daughter radiations from Pt^{197} daughter radiations from Au^{197m} included in above listing	Pt^{196}(n, γ) (HavA65) Pt^{196}(d, p) (SherrR41)
Pt^{198}	$t_{1/2}$ ($\beta\beta$) >10^{15} y sp act (FremJ52)	% 7.19 (WhiF56) Δ -29.91 (MTW) σ_c 4 (to Pt^{199}) 0.03 (to Pt^{199m}) (GoldmDT64)			
Pt^{199}	31 m (MMilE37) 30 m (LBlaJ56) 29 m (SherrR41)	☢ β^- (MMilE37) Δ -27.40 (MTW) σ_c ≈15 (GoldmDT64)	A n-capt (MLenJ35, AmaE35) chem, n-capt, excit (SherrR41) parent Au^{199} (MMilE37, BeacL49, MeeJ49, HillR50a)	β^- 1.69 max γ 0.075 + Au K X-ray (9%), 0.197 (9%), 0.245 (4%), 0.32 (8%, doublet), 0.475 (12%, doublet), 0.540 (24%), 0.715 (3%), 0.790 (2%), 0.960 (2%)	Pt^{198}(n, γ) (AmaE35, MLenJ35, MMilE37, SherrR41, SerL47b, HumV51)
Pt^{199m}	14.1 s (WahM59)	☢ IT (WahM59) Δ -26.98 (LHP, MTW)	B n-capt, sep isotopes (WahM59)	γ Pt X-rays, 0.393 (90%) e^- 0.018, 0.029, 0.315, 0.381	Pt^{198}(n, γ) (WahM59)
Pt^{200}	11.5 h (RoyL57a)	☢ β^- (RoyL57a) Δ -27 (MTW)	B n-capt, chem, genet (RoyL57a) parent Au^{200} (RoyL57a)	daughter radiations from Au^{200}	Pt^{198}(n, γ)Pt^{199}(n, γ) (RoyL57a)
Pt^{201}	2.3 m (FacJ62) 2.5 m (GopK63)	☢ β^- (FacJ62, GopK63) Δ -23.5 (MTW)	B chem, genet (FacJ62) parent Au^{201} (FacJ62)	β^- 2.66 max γ 0.15, 0.23, 1.76 daughter radiation from Au^{201}	Hg^{204}(n, α) (FacJ62, GopK63)
$_{79}$Au^{177}	1.4 s (SiiA65b)	☢ α (SiiA65b)	C excit, sep isotopes (SiiA65b)	α 6.11	F^{19} on Yb (SiiA65b)
Au^{178}	2.7 s (SiiA65b)	☢ α (SiiA65b)	C excit, sep isotopes (SiiA65b)	α 5.91	F^{19} on Yb (SiiA65b)
Au^{179}	7.1 s (SiiA65b)	☢ α (SiiA65b)	C excit, sep isotopes (SiiA65b)	α 5.84	F^{19} on Yb (SiiA65b)
Au^{181}	10 s (SiiA65b)	☢ α (SiiA65b)	C excit, sep isotopes (SiiA65b)	α 5.60, 5.47	F^{19} on Yb (SiiA65b)
Au^{183}	44 s (SiiA65b)	☢ α (SiiA65b)	C excit, sep isotopes (SiiA65b)	α 5.34	F^{19} on Yb (SiiA65b)
Au^{185}	7 m (AlboG60)	☢ [EC] (AlboG60)	C genet (AlboG60) daughter Hg^{185}, parent Pt^{185} (AlboG60) possibly identical to 4.3 m Au^{185} (LHP)		daughter Hg^{185} (AlboG60)
Au^{185}	4.33 m (SiiA65b) 4.3 m (RasJ53)	☢ EC, β^+, α ≈0.01% (ThomS49, RasJ53)	B chem, excit (ThomS49) excit, sep isotopes (SiiA65b)	α 5.07	F^{19} on Yb (SiiA65b) protons on Pt, Au (ThomS49, RasJ53)
Au^{186}	12 m (AlboG60) ≈15 m (SmiW55)	☢ EC (SmiW55, AlboG60)	B chem, genet (SmiW55, AlboG60) parent Pt^{186} (SmiW55) daughter Hg^{186} (AlboG60)	γ Pt X-rays, 0.16, 0.22, 0.30, 0.40 daughter radiations from Pt^{186}	daughter Hg^{186} (AlboG60)
Au^{187}	8 m (AlboG60)	☢ EC (AlboG60)	C genet (AlboG60) parent Pt^{187}, daughter Hg^{187} (AlboG60)	γ Pt X-rays daughter radiations from Pt^{187}	daughter Hg^{187} (AlboG60)
Au^{188}	8 m (PofN60, AlboG60) ≈10 m (SmiW55) 4.5 m (ChacK57)	☢ EC (SmiW55, PofN60, AlboG60) β^+ (ChacK57)	B chem, genet (SmiW55, PofN60, AlboG60) chem, excit (ChacK57) parent Pt^{188} (SmiW55) daughter Hg^{188} (PofN60, AlboG60)	γ Pt X-rays, 0.25, 0.33, 0.63	Ta^{181}(C^{12}, 5n) (ChacK57) protons on Pt (SmiW55) daughter Hg^{188} (PofN60, AlboG60)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{79}$Au^{189}	30 m (PofN60, AlboG60) <<40 m, activity not observed (LilG64) 42 m (SmiW55)	☢ [EC] no α, lim 3 x 10^{-5}% (KarrM63)	B chem, genet, cross bomb (SmiW55) chem, mass spect (KilPi65) parent Pt^{189}, daughter Hg^{189} (SmiW55, ChacK57)	γ Pt X-rays e$^-$ 0.027, 0.036, 0.088, 0.137, 0.154, 0.166, 0.269 daughter radiations from Pt^{189}	Au^{197}(p, 9n)Hg^{189}(EC) (PofN60, AlboG60) Ta^{181}(C^{12}, 4n) (SmiW55)
Au^{190}	39 m (AndeG61, JasJ61a) 45 m (PofN60)	☢ EC (AlboG59, AlboG60, PofN60) EC 98%, β$^+$ 2% (JasJ61a) β$^+$ <1% (AlboG59) no α, lim 1 x 10^{-6}% (KarrM63) Δ -33 (MTW)	B genet (AndeG61, JasJ61a) daughter Hg^{190} (AndeG61)	γ Pt X-rays, 0.29 (↑ 100, complex), 0.60 (↑ 5, complex), other weak γ's to 3.5 e$^-$ 0.22, 0.29	daughter Hg^{190} (AndeG61, JasJ61a)
Au$^{191-193}$	2.0 s (HenrA53)	☢ (HenrA53)	F excit (HenrA53)		protons on Tl, Hg (HenrA53)
Au^{191}	3.2 h (AndeG61a) others (SmiW55, GillL54)	☢ EC (SmiW55) no α, lim 5 x 10^{-6}% (KarrM63) Δ -34 (MTW)	A chem, genet (SmiW55, GillL54) parent Pt^{191} (SmiW55) daughter Hg^{191} (SmiW55, GillL54)	γ Pt X-rays, 0.14 (↑ 10), 0.30 (↑ 60), 0.39 (↑ 5), 0.48 (↑ 4), 0.60 (↑ 10), all γ's complex e$^-$ 0.035, 0.046, 0.054, 0.080, 0.089 many others between 0 and 2.0 daughter radiations from Pt^{191}	protons on Pt (MarkI62) Ir^{191}(α, 4n) (WilkG49a, EwbW60) Pt^{192}(d, 3n) (WilkG49a)
Au^{192}	4.1 h (FinR52) others (WilkG49a, EngeT53)	☢ EC, β$^+$ ≈1% (WilkG49a) Δ -33.0 (MTW)	A chem, excit (WilkG49a) chem, genet (FinR52, GillL54) genet energy levels (GillL54) daughter Hg^{192} (FinR52, GillL54)	γ Pt X-rays, 0.137, 0.158, 0.296, 0.308, 0.317, others between 0.1 and 1.2 e$^-$ 0.032, 0.143, 0.23, 0.30 β$^+$ 2.2 max	daughter Hg^{192} (HuqM57, GillL54) Ir^{191}(α, 3n) (WilkG49a)
Au^{193}	15.8 h (WilkG49a) 17.5 h (EwaG57) 15.3 h (FinR52)	☢ EC, no β$^+$ (lim 0.08%) (EwaG57) no α, lim 1 x 10^{-5}% (KarrM63) Δ -33 (MTW)	B chem, genet (WilkG49a) daughter Hg^{193} (GillL54, FinR52) parent Pt^{193m} (WilkG49a)	γ Pt X-rays, 0.114 (5%, complex), 0.18 (11%, complex), 0.26 (9%, doublet), 0.378 (1.4%), 0.440 (3%) e$^-$ 0.034, 0.095, 0.108, 0.177	Ir^{191}(α, 2n) (WilkG49a) deuterons on Pt (WilkG49a) daughter Hg^{193} (EwaG57) protons on Pt (MarkI62)
Au^{193m}	3.9 s (FiscV55) 3.8 s (BrunnJ55)	☢ IT (FiscV55, BrunnJ55, GillL54) EC 0.03% (BrunnJ55) Δ -33 (LHP, MTW)	B genet (BrunnJ55) daughter Hg^{193m} (GillL54, BrunnJ55) parent Pt^{193m} (0.03%) (BrunnJ55)	γ Au X-rays, 0.258 (65%) e$^-$ 0.019, 0.030	daughter Hg^{193m} (BrunnJ55) protons on Pt (FiscV55)
Au^{194}	39.5 h (WilkG49a) others (StefR49)	☢ EC ≈97%, β$^+$ ≈3% (WilkG49a) Δ -32.21 (MTW)	A chem, excit (WilkG49a) genet energy levels (ThieM56a) daughter Hg^{194} (BrunnJ55a, MerE61a, BellL64)	β$^+$ 1.49 max e$^-$ 0.250, 0.315, many others between 0.02 and 2.4 γ Pt X-rays, 0.294 (12%), 0.328 (68%), 1.469 (8%), 1.596 (3%), 1.887 (4%), 2.044 (4%), many others between 0.1 and 2.4	deuterons on Pt (WilkG49a) Ir^{193}(α, 3n) (WilkG49a) protons on Pt (StefR49)
Au^{195}	183 d (HarbG63) 185 d (BonnN62) 192 d (BisA59) 199 d (BresM60) others (StefR49, WilkG49a)	☢ EC (WilkG49a) Δ -32.55 (LHP, MTW)	A chem, genet (WilkG49a) descendant Hg^{195m} (BradC54) daughter Hg^{195} (GillL54)	γ Pt X-rays, 0.099 (10%), 0.129 (1%) e$^-$ 0.018, 0.028, 0.085	deuterons on Pt (WilkG49a) Ir^{193}(α, 2n) (WilkG49a) Pt^{195}(p, n) (StefR49)
Au^{195m}	30.6 s (FiscV55) others (HubeO52)	☢ IT (HubeO52a) Δ -32.23 (LHP, MTW)	B chem, genet (HubeO52a) excit (FiscV55) daughter Hg^{195m} (HubeO52a, JolyR55) not daughter Hg^{195} (HubeO53, GillL54)	γ Au X-rays, 0.261 (77%) e$^-$ 0.044, 0.056, 0.180	daughter Hg^{195m} (HubeO52a, JolyR55) protons on Pt (FiscV55)
Au^{196}	6.18 d (IkeH63) others (BonnN62, WapA62, TilR63a, LingE62, BakM60, WilkG49a, StefR49, WafH48, KriR41c)	☢ EC 93.8%, β$^-$ 6.2% (BergO61) β$^+$ 5 x 10^{-5}% (IkeH63) others (StefR49, WilkG49a, ThieM56) Δ -31.15 (MTW)	A chem, excit (MMilE37)	β$^-$ 0.259 max (6%) e$^-$ 0.255, 0.277, 0.343 γ Pt X-rays, 0.333 (25%), 0.356 (94%), 0.426 (6%), 1.091 (0.2%)	Pt^{196}(d, 2n) (WapA62) Pt^{196}(p, n) (StefR49, IkeH63, MarkI62) Pt^{195}(d, n) (KriR41c, WilkG49a, StahP52) Ir^{193}(α, n) (EwbW60) Au^{197}(n, 2n) (MMilE37, WilkG49a, WapA62)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{79}$Au^{196m}	9.7 h (BonnN62) others (KavT60, BakM60, AdemM60, VLieR59, TilR63a, WilkG49a, MMilE37)	☢ IT (WapA62a) Δ −30.56 (LHP, MTW)	A chem, excit (MMilE37, TilR63a)	γ Au X-rays, 0.148 (42%), 0.188 (32%), 0.285 (5%), 0.316 (5%) e^- 0.069, 0.081, 0.094, 0.108, 0.135, 0.160 daughter radiations from Au^{196}	Pt^{196}(d, 2n) (WapA62a, VLieR59) Au^{197}(n, 2n) (MMilE37, WilkG49a, VLieR59) Au^{197}(p, pn) (TilR63a)
Au^{197}		% 100 Δ −31.17 (MTW) σ_c 98.8 (GoldmDT64)			
Au^{197m}	7.2 s (FiscV55) 7.4 s (FrauH47) 7.5 s (WieM45a)	☢ IT (WieM45a) Δ −30.76 (LHP, MTW)	A excit (WieM45a) daughter Hg^{197m} (FrauH50a, DShaA52, HavA65) daughter Pt^{197m} (PraK64, HavA65)	γ Au X-rays, 0.130 (8%), 0.279 (75%) e^- 0.050, 0.117, 0.127, 0.198, 0.265	daughter Hg^{197m}, Pt^{197m} (HavA65)
Au^{198}	2.697 d (LocE53, JohaK56) 2.699 d (BellRE54, RobeJ60) 2.687 d (StarS63) 2.686 d (TobJ55) 2.704 d (KeeJ58) others (SasC56, SinW51, SilL51, DieG46, HumV51, SerL47b, SherrR41, PoolM37, WriH57)	☢ β^- (MMilE37) no EC(K) lim 0.01% (BashA56) no β^+, lim 0.003% (MimW51) Δ −29.59 (MTW) σ_c 26,000 (GoldmDT64)	A chem, n-capt (AmaE35, MMilE37)	β^- 0.962 max average β^- energy: 0.32 calorimetric (ShimN56a) 0.29 calorimetric (LecM64) e^- 0.329, 0.398 γ 0.412 (95%), 0.676 (1%), 1.088 (0.2%)	Au^{197}(n, γ) (AmaE35, MMilE37, PoolM37, DzhB41, SerL47b, HumV51) Pt^{198}(p, n) (StefR49, StefR48)
Au^{199}	3.15 d (BellRE55) others (WriH57, DShaA52, MMilE37, GleG64)	☢ β^- (KriR41c) Δ −29.09 (MTW) σ_c ≈30 (GoldmDT64)	A chem, genet (MMilE37) daughter Pt^{199} (MMilE37, BeacL49a, MeeJ49, HillR50a)	β^- 0.46 max (6%), 0.30 max γ Hg X-rays, 0.158 (37%), 0.208 (8%) e^- 0.075, 0.125, 0.145	Pt^{198}(n, γ)Pt^{199}(β^-) (MMilE37, HahR63, LindsJ63a) Au^{197}(n, γ)Au^{198}(n, γ) (HillR50) Pt^{198}(d, n) (KriR41c)
Au^{200}	48.4 m (RoyJ59) others (ButeF52a, MauW42, GirR60)	☢ β^- (SherrR41) Δ −27.3 (MTW)	B chem (SherrR41) chem, sep isotopes, excit (ButeF52a) daughter Pt^{200} (RoyL57a)	β^- 2.2 max γ 0.368 (24%), 1.227 (23%), 1.593 (1%)	Hg^{202}(d, α) (GirR60) Tl^{203}(n, α) (ButeF52a) Hg^{201}(γ, p) (ButeF52a)
Au^{201}	26 m (ErdP57, ButeF52a) others (FacJ62, EutP62)	☢ β^- (ButeF52a) Δ −26.2 (MTW)	B chem, excit, sep isotopes (ButeF50, ButeF52a) daughter Pt^{201} (FacJ62)	β^- 1.5 max γ 0.53	Hg^{202}(γ, p) (ButeF50, ButeF52a, EutP62)
Au$^{202, 204}$	≈25 s (ButeF52a)	☢ β^- or IT (ButeF52a)	E excit (ButeF52a)		Hg$^{202, 204}$(n, p) (ButeF52a)
Au^{203}	55 s (ButeF52a)	☢ β^- (ButeF52a) Δ −23 (MTW)	B chem, excit, sep isotopes (ButeF52a)	β^- 1.9 max γ 0.69	Hg^{204}(γ, p) (ButeF52a)
$_{80}$Hg$^{<195}$	0.7 m (RasJ53)	☢ α (RasJ53)	E chem (ThomS49, RasJ53) probably Hg^{185} or Hg^{186} (LHP)	α 5.6	deuterons on Au^{197} (RasJ53)
Hg^{185}	50 s (AlboG60)	☢ [EC] (AlboG60)	C chem, mass spect (AlboG60) parent 7 m Au^{185} (AlboG60)		Au^{197}(p, 13n) (AlboG60)
Hg^{186}	1.5 m (AlboG60)	☢ EC (AlboG60)	B chem, mass spect (AlboG60) parent Au^{186} (AlboG60)	γ Au X-rays, 0.125, 0.27, 0.35, 0.44 daughter radiations from Au^{186}	Au^{197}(p, 12n) (AlboG60)
Hg^{187}	3 m (AlboG60)	☢ EC (AlboG60) α? (KarrM63)	B chem, mass spect (AlboG60) parent Au^{187} (AlboG60)	γ Au X-rays, 0.175, 0.255, 0.40 daughter radiations from Au^{187}	Au^{197}(p, 11n) (AlboG60)
Hg^{188}	3.7 m (PofN60, AlboG60) 3.0 m (α) (KarrM63)	☢ EC (PofN60, AlboG60) α (?) (KarrM63)	B chem, mass spect (PofN60, AlboG60) parent Au^{188} (PofN60, AlboG60)	γ Au X-rays, 0.14 α 5.14 (? may be Hg^{187}) daughter radiations from Au^{188}	Au^{197}(p, 10n) (PofN60, AlboG60, KarrM63a)

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$_{80}$Hg^{189}	9.6 m (AndeG61) 9 m (PofN60, AlboG60)	☢ EC, β^+ ? (PofN60, AlboG60, AndeG61) no α, lim 3 x 10^{-5}% (KarrM63)	A chem, mass spect (PofN60, AlboG60, AndeG61) parent Au^{189} (SmiW55, ChacK57) ancestor Pt^{189} (PofN60, AlboG60, AndeG61)	γ Au X-rays, 0.165, 0.24, 0.32, 0.50 daughter radiations from Au^{189}	Au^{197}(p, 9n) (PofN60, AlboG60, AndeG61)
Hg^{190}	20 m (AndeG61, JasJ64) 21 m (AlboG59, AlboG60, PofN60) others (GillL54, ChacK57, SmiW55)	☢ EC (AlboG59, AlboG60, PofN60) no β^+, lim 1% (AlboG59) no α, lim 5 x 10^{-5}% (KarrM63) Δ -31 (NDS, MTW)	A chem, mass spect (AlboG59, AndeG61, JasJ61b) parent Au^{190} (AndeG61)	γ Au X-rays, 0.14 (complex) e^- 0.015, 0.026, 0.049, 0.062, 0.076 daughter radiations from Au^{190}	Au^{197}(p, 8n) (AlboG59, AndeG61, JasJ61b, AlboG60, PofN60)
Hg$^{<191}$	90 m (GillL54)	☢ (GillL54)	F excit (GillL54)		protons on Au^{197} (GillL54)
Hg$^{<191}$	≈3 h (GillL54)	☢ (GillL54)	F excit (GillL54)	e^- 0.088	protons on Au^{197} (GillL54)
Hg^{191}	55 m (PofN60, SmiW55) 57 m (GillL54) no 12 h Hg^{191} observed (SmiW55)	☢ EC (SmiW55)	A excit (GillL54) chem, genet (SmiW55) mass spect (AndeG61a, PofN60) parent Au^{191} (SmiW55, GillL54)	γ Au X-rays, 0.26 (complex) e^- 0.170, 0.191, 0.239 daughter radiations from Au^{191}	Au^{197}(p, 7n) (GillL54, AndeG61a, PofN60)
Hg^{192}	4.8 h (JasJ61) 5.7 h (FinR52) 6.3 h (VinA55a)	☢ EC, β^+ (FinR52) β^+ <1% (JasJ61) no α, lim 4 x 10^{-6}% (KarrM63) Δ -32 (MTW)	B chem, excit (FinR52, GillL54) parent Au^{192} (FinR52, GillL54)	γ Au X-rays, 0.114 (↑ 10), 0.157 (↑ 20), 0.274 (↑ 100) e^- 0.017, 0.028, 0.034, 0.039, 0.077 daughter radiations from Au^{192}	Au^{197}(p, 6n) (GillL54, HuqM57)
Hg^{193}	≈6 h (GillL54) 4 h (MalyT58)	☢ EC (GillL54) Δ -31 (MTW)	B genet (GillL54) daughter Hg^{193m} (GillL54, BrunnJ55) parent Au^{193} (GillL54, FinR52)	γ Au X-rays, 0.187, 0.574, 0.762, 0.855, 1.04, 1.08 e^- 0.025, 0.035, 0.108, 0.174 daughter radiations from Au^{193}	Au^{197}(p, 5n) (FireE52, GillL54, EwaG57)
Hg^{193m}	10.0 h (FireE52) 11 h (BrunnJ58) others (VinA55a, GillL54)	☢ EC 84%, IT 16% (GillL54) β^+ 1.5% (BrunnJ58) EC(K)/EC(L) 7.3 (BrunnJ58) no α, lim 1 x 10^{-5}% (KarrM63) Δ -31 (LHP, MTW)	B chem, excit (FireE52, GillL54) parent Hg^{193} (GillL54) parent Au^{193m} (GillL54, BrunnJ55)	γ Hg X-rays, Au X-rays, 0.218, 0.258, 0.574, many others between 0.1 and 1.6 e^- 0.020, 0.025, 0.029, 0.036, 0.087, 0.178, 0.243, many others between 0 and 1.6 daughter radiations from Hg^{193} daughter radiations from Au^{193m} included in above listing	Au^{197}(p, 5n) (FireE52, GillL54, EwaG57)
Hg^{194}	1.9 y (BellL64) 0.40 y (same activity?) (MerE61a) ≈1.6 y (BrunnJ58) 0.4 y (BrunnJ55a, MalyT58)	☢ EC(L), no EC(K) (BellL64) EC(K) (MerE61a) no β^+, lim 1% (MerE61a) Δ -32.2 (BellL64, MTW)	B chem, genet (BrunnJ55a, MerE61a, BellL64) parent Au^{194} (MerE61a, BrunnJ55a, BellL64)	γ Au X-rays daughter radiations from Au^{194}	Au^{197}(p, 4n) (BrunnJ55a, BellL64)
Hg^{194m}	0.4 s (HenrA53)	☢ [IT or EC]	E excit (HenrA53)	γ 0.048, 0.134	protons on Au and Hg (HenrA53)
Hg^{195}	9.5 h (JolyR55, BrunnJ54, HubeO53)	☢ EC (JolyR55) Δ -31 (MTW)	A chem, genet, excit (GillL54) mass spect (JunB61a) daughter Hg^{195m} (GillL54) daughter Tl^{195} (KniJD55) parent Au^{195} (GillL54) not parent Au^{195m} (HubeO53, GillL54)	γ Au X-rays, 0.20 (complex), 0.261, 0.59 (doublet), 0.780, 0.930, 1.110, 1.172 e^- 0.048, 0.058, 0.099	daughter Tl^{195} (KniJD55, JunB61a) Au^{197}(p, 3n) (TilR63a, GillL54)
Hg^{195m}	40.0 h (HubeD53, JolyR55, BrunnJ54) others (TilR63a)	☢ EC 50%, IT 50% (JolyR55, BrunnJ54) EC 52%, IT 48% (GillL54) Δ -31 (LHP, MTW)	A chem, excit (FinR52) chem, excit, genet (GillL54) mass spect (JunB61a) parent Au^{195m} (HubeO52, JolyR55) parent Hg^{195} (GillL54) not daughter Tl^{195} (KniJD55) ancestor Au^{195} (BradC54)	γ Hg X-rays, Au X-rays, 0.200 (35%), 0.261 (20%), 0.560 (20%) e^- 0.0014, 0.013, 0.022, 0.034, 0.043, 0.048, 0.053, 0.058, 0.109, 0.120, 0.180 daughter radiations from Hg^{195} daughter radiations from Au^{195m} included in above listing	Au^{197}(p, 3n) (TilR63a, GillL54)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12} = 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{80}$Hg^{196}	$t_{1/2}$ (α) >1 × 10^{14} y sp act (MacfR61a)	% 0.146 (NierA50a) Δ −31.84 (MTW) σ_c 880 (to Hg^{197}) 25 (to Hg^{197m}) (GoldmDT64)			
Hg^{197}	65 h (HubeO51, TilR63a) others (CorkJ52, FrieG43, SherrR41, KriR40b, KriR41a)	☢ EC (FrieG43) Δ −30.75 (DWitS65, MTW)	A chem, excit, cross bomb (WuC41, FrieG43) daughter Hg^{197m} (HubeO53) daughter Tl^{197} (KniJD55)	γ Au X-rays, 0.077 (18%), 0.191 (2%), 0.268 (0.15%) e^- 0.064, 0.074	Au^{197}(p, n) (TilR63a) Au^{197}(d, 2n) (FrieG43, WuC41)
Hg^{197m}	24 h (BradC54, TilR63a) others (FrieG43, HubeO51, MMilE37)	☢ IT 94%, EC 6% (HavA65) others (DShaA52, JolyR55) Δ −30.45 (LHP, MTW)	A n-capt (AndeEB36) chem (MMilE37) chem, excit, cross bomb (WuC41, FrieG43) parent Au^{197m} (FrauH50a, DShaA52, HavA65) parent Hg^{197} (HubeO53) not daughter Tl^{197} (KniJD55)	γ Hg X-rays, 0.134 (42%), 0.279 (7%) e^- 0.051, 0.082, 0.120, 0.131, 0.152, 0.162 daughter radiations from Hg^{197} daughter radiations from Au^{197m} included in above listing	Au^{197}(p, n) (TilR63a) Au^{197}(d, 2n) (WuC41, FrieG43)
Hg^{198}		% 10.02 (NierA50a) Δ 30.97 (MTW) σ_c 0.02 (to Hg^{199m}) (GoldmDT64)			
Hg^{199}		% 16.84 (NierA50a) Δ −29.55 (MTW) σ_c 2000 (GoldmDT64)			
Hg^{199m}	43 m (SmeF65, MMilE37, HeyF37) 44 m (HoleN47a, MacD48) others (PoolM37, WuC41, SherrR41, WieM45a)	☢ IT (FrieG43) Δ −29.01 (LHP, MTW)	A chem, excit (HeyF37, MMilE37) mass spect (BergI49a) not daughter Tl^{199} (BergI53)	γ Hg X-rays, 0.158 (53%), 0.375 (15%) e^- 0.075, 0.144, 0.285, 0.354	Hg^{198}(d, p) (KriR40b) Pt^{196}(α, n) (SherrR41) Hg^{200}(n, 2n) (MMilE37, HeyF37) Hg^{199}(n, n) (FrieG43, WuC41, BergI49a)
Hg^{200}		% 23.13 (NierA50a) Δ −29.50 (MTW) σ_c <50 (GoldmDT64)			
Hg^{201}		% 13.22 (NierA50a) Δ −27.66 (MTW) σ_c <50 (GoldmDT64)			
Hg^{202}		% 29.80 (NierA50a) Δ −27.35 (MTW) σ_c 4 (GoldmDT64)			
Hg^{203}	46.9 d (EicG56) 46.6 d (GleG64) 47.9 d (CorkJ52) others (LyoW51, WilsH51, WriH57, CaliJ59, SherrR41, IngM47b, SerL47b, MauW42)	☢ β^- (FrieG43) Δ −25.26 (MTW)	A excit (KriR40b) chem, excit, n-capt (WuC41, FrieG43) mass spect (SlaH49a, BergI49)	β^- 0.214 max e^- 0.194, 0.264, 0.275 γ 0.279 (77%)	Hg^{202}(n, γ) (FrieG43, WuC41, IngM47b, SerL47b)
Hg^{204}		% 6.85 (NierA50a) Δ −24.69 (MTW) σ_c 0.4 (GoldmDT64)			
Hg^{205}	5.5 m (MauW42, KriR40b) 5.6 m (LyoW51) others (WuC41, FrieG43)	☢ β^- (KriR40b) Δ −22.2 (MTW)	A n-capt, excit (KriR40b, KriR42) sep isotopes, n-capt (LyoW51)	β^- 1.7 max γ 0.205	Hg^{204}(n, γ) (LyoW51) Hg^{204}(d, p) (KriR40b, KriR42)
Hg^{206}	8.1 m (WolfGK64) 8.5 m (KauP62) others (NurM61)	☢ β^- (NurM61) Δ −20.95 (MTW)	A chem, genet (NurM61, KauP62) daughter Pb^{210} (RaD), parent Tl^{206} (NurM61, KauP62, WolfGK64)	β^- [1.3 max] γ 0.31 daughter radiations from Tl^{206}	daughter Pb^{210} (NurM61, KauP62, WolfGK64) Pb^{208}(p, 3p) (KauP62)

Isotope Z A	Half-life	Type of decay (☢), % abundance; Mass excess (Δ≡M−A), MeV (C^{12} ≡ 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{81}\mathrm{Tl}^{191}$	10 m (ChacK60) <10 m (AndeG61a)	☢ EC, β^+ (ChacK60)	B chem, sep isotopes (ChacK60) chem, mass spect (AndeG61a)	γ Hg X-rays, 0.511 ($\gamma^\pm$)	$W^{182}(N^{14}, 5n)$ (ChacK60) protons on Hg (AndeG61a)
Tl^{192}	11 m (AndeG61a) 10 m (DiaR63a)	☢ [EC, β^+] (AndeG61a)	B chem, mass spect (AndeG61a) excit, cross bomb (DiaR63a)	γ [Hg X-rays], 0.424, [0.511 ($\gamma^\pm$)] e^- 0.341	$Ta^{181}(O^{16}, 5n)$ (DiaR63a) C^{12} on Re (DiaR63a) protons on Hg (AndeG61a)
Tl^{193}	23 m (AndeG61a) 30 m (ChacK60)	☢ EC, β^+ (ChacK60, AndeG61a) no α, lim 2 x 10^{-4}% (KarrM63)	B chem, sep isotopes (ChacK60) chem, mass spect (AndeG61a)	γ Hg X-rays, 0.158, 0.169, 0.178, 0.187, 0.208, 0.216, 0.238 0.247, 0.511 ($\gamma^\pm$), if electrons observed by (AndeG61a) are all K-lines converted in Hg e^- 0.24	$W^{184}(N^{14}, 5n)$ (ChacK60) protons on Hg (AndeG61a)
Tl^{193m}	2.1 m (DiaR63a)	☢ [IT] (DiaR63a)	C excit, cross bomb (DiaR63a)	γ Tl X-rays, 0.365 e^- 0.280	$Ta^{181}(O^{16}, 4n)$, $Re^{185}(C^{12}, 4n)$ (DiaR63a)
Tl^{194}	33.0 m (JunB60)	☢ EC (JunB60) no α, lim 1 x 10^{-7}% (KarrM63) Δ −26 (MTW)	A chem, mass spect, genet (JunB60) daughter Pb^{194} (JunB60)	γ Hg X-rays, 0.427 e^- 0.344	protons on Hg (JunB60) daughter Pb^{194} (JunB60)
Tl^{194m}	32.8 m (JunB60)	☢ EC, no IT observed (JunB60)	B chem, mass spect (JunB60) not daughter Pb^{194} (JunB60)	γ Hg X-rays, 0.097 e^- 0.083	protons on Hg (JunB60)
Tl^{195}	1.16 h (JunB61a) others (KniJD55, AndeG57)	☢ EC (AndeG57) β^+ (weak) (JunB61a) no α, lim 3 x 10^{-7}% (KarrM63) Δ −28 (MTW)	B chem, genet (KniJD55) mass spect, genet energy levels (AndeG57) parent Hg^{195} (KniJD55) not parent Hg^{195m} (KniJD55)	γ Hg L X-rays, others e^- 0.022, 0.034 β^+ 1.8 max daughter radiations from Hg^{195}	$Hg^{196}(d, 3n)$ (KniJD55) protons on Hg (JunB61a)
Tl^{195m}	3.5 s (AndeG57a) 3.6 s (DiaR63a)	☢ IT (AndeG57a) Δ −28 (LHP, MTW)	B chem (AndeG57a) excit (DiaR63a) daughter Pb^{195} (AndeG57a)	γ Tl L X-rays, 0.383 (95%) e^- 0.084, 0.096	daughter Pb^{195} (AndeG57a) $Re^{187}(C^{12}, 4n)$ (DiaR63a)
Tl^{196}	1.84 h (JunB60) others (AndeG58, VVijR63)	☢ EC (AndeG55) Δ −27.2 (MTW)	A chem, genet energy levels, mass spect (AndeG58, AndeG55, AndeG57, JunB60) daughter Pb^{196} (AndeG57)	γ Hg X-rays, 0.426 e^- 0.343	daughter Pb^{196} (AndeG57, AndeG58, JunB60) protons on Hg (JunB60) $Au^{197}(\alpha, 5n)$ (VVijR63)
Tl^{196m}	1.41 h (JunB60)	☢ EC 96%, IT 4% (JunB60) Δ −26.8 (LHP, MTW)	A chem, mass spect, genet energy levels (JunB60) excit (VVijR63) not daughter Pb^{196} (JunB60)	γ Hg X-rays, 0.426, others e^- 0.071, 0.081, 0.107, others daughter radiations from Tl^{196}	protons on Hg (JunB60) $Au^{197}(\alpha, 5n)$ (VVijR63)
Tl^{197}	2.84 h (JunB61) others (KniJD55, AndeG57, AndeG55)	☢ EC (AndeG55) Δ −28.5 (MTW, DWitS65)	A chem, excit, genet (KniJD55) mass spect, genet energy levels (AndeG55) parent Hg^{197} (KniJD55) not parent Hg^{197m} (KniJD55)	γ Hg X-rays, 0.152, 0.426 e^- 0.067, 0.137 daughter radiations from Hg^{197}	$Au^{197}(\alpha, 4n)$ (VVijR63, KniJD55) $Hg^{198}(d, 3n)$ (KniJD55)
Tl^{197m}	0.54 s (HenrA53) 0.55 s (SchmW65a) others (DiaR63a, AndeG57a)	☢ IT (AndeG57a) Δ −27.9 (LHP, MTW)	A excit (HenrA53) chem (AndeG57a) excit, genet energy levels (DiaR63a)	γ Tl X-rays, 0.222 (40%), 0.385 (90%) e^- 0.136, 0.207, 0.219, 0.300	daughter Pb^{197m} (AndeG55, AndeG57) $Au^{197}(\alpha, 4n)$ (DiaR63a)
Tl^{198}	5.3 h (MicM54) others (BergI53)	☢ EC (AndeG55) β^+ ≈0.7% (GupR61) no α, lim 3 x 10^{-7}% (KarrM63) Δ −27.5 (MTW)	A chem, genet energy levels (BergI53) excit (VVijR63) mass spect (MicM54) genet (JunB59, GupR61, LindgI58) daughter Pb^{198} (JunB59, GupR61, LindgI58) descendant Po^{198} (BrunC65a)	γ Hg X-rays, 0.412 (90%), 0.65 (40%, complex), 1.20 (21%), 1.42 (24%), 2.01 (15%), 2.45 (5%), 2.78 (2%) β^+ 2.4 max e^- 0.111, 0.201, 0.317, 0.329, others	daughter Pb^{198} (JunB59, GupR61, LindgI58) $Au^{197}(\alpha, 3n)$ (VVijR63) deuterons on Hg (BergI53)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{81}$Tl^{198m}	1.87 h (JunB60) 1.90 h (FiscP56) others (OrtD49, BergI53)	☢ IT 55%, EC 45% (JunB60) others (FiscP56, BergI53) Δ −27.0 (LHP, MTW)	A chem, excit (OrtD49, BergI53) mass spect (MicM54, JunB60) genet energy levels (FiscP56) daughter Pb^{198m} (NeumH50a, KarrD51)	γ Hg X-rays, Tl X-rays, 0.283 (30%), 0.412 (45%), 0.586 (35%), 0.635 (35%) e$^-$ 0.033, 0.046, 0.175, 0.197, 0.246 daughter radiations from Tl^{198}	Au^{197}(α, 3n) (FiscP56, MicM54, BrinGO57)
Tl^{199}	7.4 h (JunB60a, MicM54) others (OrtD49)	☢ EC (OrtD49) no β$^+$ (IsrH51) Δ −28.5 (MTW)	A chem (KriR40b) chem, excit (OrtD49) mass spect (MicM54, JunB60a) daughter Pb^{199} (NeumH50a) not parent Hg^{199m} (BergI53) descendant Po^{199}, Po^{199m} (BrunC65a)	γ Hg X-rays, 0.158 (5%), 0.208 (12%), 0.247 (9%), 0.455 (14%) e$^-$ 0.035, 0.125, 0.161, 0.193	Au^{197}(α, 2n) (VVijR63) Hg^{199}(d, 2n) (KriR40b)
Tl^{200}	26.1 h (JansJ62) others (HerrlC57, OrtD49, MicM54)	☢ EC (OrtD49) β$^+$ 0.37% (VNooB62, LHP) Δ −27.05 (MTW)	A chem, excit (OrtD49) mass spect (MicM54) daughter Pb^{200} (NeumH50a) descendant Po^{200} (BrunC65a)	γ Hg X-rays, 0.368 (88%), 0.579 (10%), 0.829 (8%), 1.21 (35%, complex), 1.364 (4%), 1.410 (1.6%), 1.517 (4%), others β$^+$ 1.44 max (0.06%), 1.07 max (0.3%) e$^-$ 0.285, 0.354	deuterons on Hg (KriR40b, VNooB62, GupR60a) Au^{197}(α, n) (OrtD49) Tl^{203}(p, 4n) Pb^{200}(β$^-$) (SakM65)
Tl^{201}	74 h (HerrlC60) 72 h (NeumH50a) others (KriR40b)	☢ EC (NeumH50a) Δ −27.3 (MTW)	A chem, mass spect, genet (JohaB59, HerrlC60) chem, excit, cross bomb (NeumH50a) daughter Pb^{201} (NeumH50a, JohaB59, HerrlC60) descendant Po^{201}, Po^{201m} (BrunC65a)	γ Hg X-rays, 0.135 (2%), 0.167 (8%) e$^-$ 0.016, 0.052, 0.084	daughter Pb^{201} (NeumH50a) deuterons on Hg (KriR40b, LingdI58)
Tl^{202}	12.0 d (HameH57) others (MartiHC52, WilkG50b, FajK41a)	☢ EC (KriR40b, MauW42) no β$^+$, β$^-$ (WilkG50b) Δ −26.13 (MTW)	A chem, excit (KriR40b, FajK41a) daughter Pb^{202} (HuiJ54)	γ Hg X-rays, 0.439 (95%), 0.522 (0.1%), 0.961 (0.07%) e$^-$ 0.356	Hg^{202}(d, 2n) (KriR40b) Hg^{201}(d, n), Tl^{203}(d, t) (BornP59)
Tl^{203}		% 29.50 (BaiK50) Δ −25.75 (MTW) σ$_c$ 11 (GoldmDT64)			
Tl^{204}	3.81 y (LeuH62) 3.80 y (HarbG63) 3.78 y (FinR59) 3.91 y (WahA59, NilR62) 3.68 y (FlyK65a) others (EdwJ58, MerW57, TobJ55c, WyaE61, HorrD54) SpenH64)	☢ β$^-$ 97.9%, EC 2.1% (LeuH62) β$^-$ 97.5%, EC 2.5% (ChrisP64) others (LidL52, DMatE52) Δ −24.34 (MTW)	A chem, n-capt (FajK40) mass spect (MicM54)	β$^-$ 0.766 max γ Hg X-rays	Tl^{203}(n, γ) (FajK40, SerL47b)
Tl^{205}		% 70.50 (BaiK50) Δ −23.81 (MTW) σ$_c$ 0.11 (GoldmDT64)			
Tl^{206}	4.19 m (SargB53) 4.23 m (FajK40) others (PouA59, AlbuD51a, PoolM37, HeyF37)	☢ β$^-$ (FajK40, KriR42) Δ −22.26 (MTW)	A n-capt (PreiP35) chem, genet (BrodE47) excit, sep isotopes (NeumH50) daughter Bi^{210} (RaE) (BrodE47) daughter Bi^{210m} (NeumH50, LevyHB54) daughter Hg^{206} (NurM61, KauP62, WolfGK64)	β$^-$ 1.52 max γ no γ	Tl^{205}(n, γ) (PreiP35, PoolM37, HeyF37, NeumH50) daughter Bi^{210m} from Bi^{209}(n, γ) (NeumH50)
Tl^{207} (AcC")	4.79 m (SargB53) 4.76 m (CuriM31, SargB39a) others (FajK40, BretE40, BaldG46)	☢ β$^-$ Δ −21.01 (MTW)	A chem, genet (CuriM31) daughter Bi^{211} (AcC)	β$^-$ 1.44 γ 0.897 (0.16%)	descendant Ac^{227} (HydE64)
Tl^{207m}	1.3 s (EccD65)	☢ IT (EccD65) Δ −19.67 (LHP, MTW)	E excit (EccD65)	γ 0.35, 1.00	Pb^{208}(t, α) (EccD65)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess $(\Delta \equiv M-A)$, MeV ($C^{12} \equiv 0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{81}$Tl^{208} (ThC″)	3.10 m (BaulD57) others (CuriM31)	☢ β^- Δ −16.76 (MTW)	A chem, genet (CuriM31) daughter Bi^{212} (ThC)	β^- 1.80 max e^- 0.187, 0.423, 0.495 γ 0.511 (23%), 0.583 (86%), 0.860 (12%), 2.614 (100%)	natural source, descendant Th^{228} (HydE64)
Tl^{209}	2.2 m (HageF50a)	☢ β^- (HageF50a) Δ −13.65 (MTW)	A chem, genet (HageF50a) daughter Bi^{213} (HageF47, EnglA47, HageF50a) parent Pb^{209} (HageF47, EnglA47)	β^- 1.99 max e^- 0.03, 0.10 γ Pb X-rays, 0.12 (50%), 0.45 (100%), 1.56 (100%) daughter radiations from Pb^{209}	descendant U^{233}, Th^{229}, Ac^{225} (HydE64)
Tl^{210} (RaC″)	1.32 m (CuriM31) others (BisG50, DevoS37)	☢ β^-; n ≈0.02% (KogA56, KogA57) Δ −9.23 (MTW)	A chem, genet (CuriM31) daughter Bi^{214} (RaC), parent Pb^{210} (RaD)	β^- 2.3 max e^- 0.208, 0.28 γ 0.296 (80%), 0.795 (100%), 1.08 (19%, complex), 1.21 (17%), 1.31 (21%), 2.01 (7%), 2.09 (5%), 2.36 (8%), 2.43 (9%)	descendant Ra^{226} (HydE64)
$_{82}$Pb^{194}	11 m (JunB60)	☢ EC (JunB60)	A chem, mass spect, genet (JunB60) parent Tl^{194}, not parent Tl^{194m} (JunB60)	γ 0.204 daughter radiations from Tl^{194}	protons on Tl (JunB60)
Pb^{195}	17 m (AndeG57)	☢ EC (AndeG57)	B chem, mass spect (AndeG57) parent Tl^{195m} (AndeG57)	γ Tl X-rays, 0.39 (doublet) e^- 0.084, 0.096, 0.30 daughter radiations from Tl^{195} daughter radiations from Tl^{195m} included in above listing	Tl^{203}(p, 9n) (AndeG57)
Pb^{196}	37 m (AndeG57, SveJ61)	☢ EC (AndeG57) no α, lim 3 x 10^{-5}% (KarrM63) Δ −24 (MTW)	A chem, genet (AndeG57) chem, mass spect (SveJ61) parent Tl^{196} (AndeG57) not parent Tl^{196m} (JunB60)	γ Tl X-rays, 0.192, 0.240, 0.253, 0.367, 0.503, others e^- 0.155, 0.168, others daughter radiations from Tl^{196}	Tl^{203}(p, 8n) (AndeG57, SveJ61)
Pb^{197}		☢ [EC] Δ −24 (MTW)	F [AndeG57]	γ Tl X-rays, 0.386 (doublet)	[daughter Pb^{197m}]
Pb^{197m}	42 m (AndeG55)	☢ EC 80%, IT 20% (AndeG57) no α, lim 3 x 10^{-4}% (KarrM63) Δ −24 (LHP, MTW)	A chem, mass spect (AndeG55, JunB62)	γ Tl and Pb X-rays, 0.085, 0.222, 0.234, 0.386 (doublet) e^- 0.069, 0.136, 0.146, 0.207, 0.219, 0.360 (doublet) daughter radiations from Pb^{197}, Tl^{197m} included in above listing	Tl^{203}(p, 7n) (AndeG55, AndeG57)
Pb^{198}	2.4 h (JunB59, AndeG57)	☢ EC (AndeG55) no α, lim 1 x 10^{-7}% (KarrM63) Δ −26 (MTW)	A chem, mass spect (AndeG55, JohaB59, JunB59) parent Tl^{198} (JunB59, GupR61, LindgI58)	γ Tl X-rays, 0.117 (3%), 0.173 (28%), 0.259 (8%), 0.290 (16%), 0.38 (40%, complex), 0.575 (4%), 0.649 (2%), 0.865 (6%) e^- 0.031, 0.088, 0.159, 0.172, 0.205, 0.270, others daughter radiations from Tl^{198}	Tl^{203}(p, 6n) (AndeG55, JohaB59, JunB59)
Pb^{198m}	25 m (KarrD51)	☢ EC (KarrD51)	G chem, genet (KarrD51) activity not observed (AndeG57)		protons on Tl (KarrD51)
Pb^{199}	90 m (AndeG55) ≈80 m (NeumH50a)	☢ EC (NeumH50a) β^+ (weak) (AndeG57) Δ −25 (MTW)	A chem, genet (NeumH50a) chem, mass spect (AndeG55) parent Tl^{199}, daughter Bi^{199} (NeumH50a) descendant Bi^{199} (NeumH50a)	γ Tl X-rays, 0.353 (17%), 0.367 (80%), 0.720 (10%) e^- 0.267 β^+ 2.8 max (?) daughter radiations from Tl^{199}	Tl^{203}(p, 5n) (JohaB59, AndeG55, AndeG57)
Pb^{199m}	12.2 m (AndeG55) others (StocR56)	☢ IT (AndeG55) Δ −25 (LHP, MTW)	B chem, mass spect (AndeG55) daughter Bi^{199} (SiiA64)	γ Pb X-rays, 0.424 (20%) e^- 0.336, 0.409 daughter radiations from Pb^{199}	Tl^{203}(p, 5n) (AndeG55)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{82}Pb^{200}$	21.5 h (BergK55) others (JohaB59, GerhT56a, NeumH50a, BelyB61)	☢ EC (NeumH50a) Δ -26 (MTW)	A chem, genet (NeumH50a) chem, mass spect (WirB63) parent Tl^{200}, daughter Bi^{200} (NeumH50a) daughter Po^{204} (KarrD51)	γ Tl X-rays, 0.109, 0.146 (doublet), 0.236, 0.26 (complex), 0.290 (doublet), 0.450, 0.605 e^- 0.024, 0.06, 0.133, 0.150, 0.172, 0.183, many others daughter radiations from Tl^{200}	$Tl^{203}(p, 4n)$ (JohaB59, BashE60, WirB63)
Pb^{201}	9.4 h (BergK55) others (WapA54d, NeumH50a)	☢ EC (NeumH50a) β^+ (weak) (AndeG57, BergK57) Δ -25 (MTW)	A chem, mass spect (JohaB59) chem, genet (NeumH50a) parent Tl^{201}, daughter Bi^{201}, daughter Bi^{201m} (NeumH50a) parent Tl^{201} (JohaB59, HerrlC60) daughter Po^{205} (KarrD51)	γ Tl X-rays, 0.330, 0.361, 0.406, 0.585, 0.766, 0.907, 0.946, 1.30, 1.40, others e^- 0.244, 0.275, 0.316 β^+ 0.55 max daughter radiations from Tl^{201}	$Tl^{203}(p, 3n)$ (JohaB59, LindsJ60) $Tl^{203}(d, 4n)$ (WapA54d)
Pb^{201m}	61 s (StocR56) others (FiscV55, HopN52)	☢ IT (HopN52) Δ -25 (LHP, MTW)	B chem, excit (HopN52) chem, genet (StocR56) daughter Bi^{201} (StocR56)	γ Pb X-rays, 0.629 (51%) e^- 0.541, 0.614	daughter Bi^{201} (StocR56) $Tl^{203}(p, 3n)$ (HopN52)
Pb^{202}	≈3 x 10^5 y yield (HuiJ54) others (TemD47a, NeumH50a)	☢ EC(L), no EC(K), lim 0.5% (HuiJ54) Δ -26.08 (MTW)	A chem, genet, mass spect (HuiJ54) parent Tl^{202} (HuiJ54)	γ Tl L X-rays daughter radiations from Tl^{202}	$Tl^{203}(d, 3n)$ (HuiJ54)
Pb^{202m}	3.62 h (AstB57a) others (MaeD54a, MaeD54b)	☢ IT 90%, EC 10% (MDonJ57) Δ -23.91 (LHP, MTW)	A chem, excit (MaeD54a, MaeD54b) chem, mass spect (MDonJ57)	γ Tl, Pb X-rays, 0.390 (7%), 0.422 (90%), 0.460 (8%), 0.490 (10%), 0.658 (35%), 0.787 (45%), 0.961 (90%) e^- 0.115, 0.126, 0.302, 0.334, 0.699, 0.772 daughter radiations from Tl^{202}	$Tl^{203}(d, 3n)$ (MaeD54a, MaeD54b)
Pb^{203}	52.1 h (BartlA58, PersL61a) others (FajK40, TemD47a, KriR40b, FajK41a, BaldG46)	☢ EC (MauW42) Δ -24.94 (MTW)	A chem, excit (MauW42) chem, excit, cross bomb (TemD47a) genet energy levels (WapA54d) mass spect (PersL61a) daughter Bi^{203} (NeumH50a)	γ Tl X-rays, 0.279 (81%), 0.401 (5%), 0.680 (0.9%) e^- 0.193, 0.264	$Tl^{203}(d, 2n)$ (TemD47a)
Pb^{203m}	6.1 s (AstB57a) others (StocR56, FiscV55, BergI55, FritA58, HopN52)	☢ IT (HopN52) Δ -24.11 (LHP, MTW)	A excit (HopN52) chem, genet (StocR56, FritA58) daughter Bi^{203} (StocR56, FritA58)	γ Pb X-rays, 0.825 (70%) e^- 0.737, 0.810	daughter Bi^{203} (StocR56, FritA58)
$\underline{Pb}^{204}$		% 1.40 (WhiF56) 1.36 (CollC52) 1.48 (NierA38) Δ -25.11 (MTW) σ_c 0.7 (GoldmDT64)			
Pb^{204m}	66.9 m (BartlA58) 67.5 m (HerrlC56) others (MauW42, FajK41a, DVriH39, BaldG46)	☢ IT (MauW42) Δ -22.92 (LHP, MTW)	A chem (FajK41a) chem, excit, genet (TemD47a, KarrD51) mass spect (MaeD54a) daughter Bi^{204} (TemD47a, SunA50, KarrD51)	γ Pb X-rays, 0.375 (93%), 0.90 (189%, doublet) e^- 0.287, 0.360, 0.824, 0.897	daughter Bi^{204} (20%) (StocR58, TemD47a, SunA50, KarrD51) $Tl^{203}(d, n)$ (FajK41a)
Pb^{205}	3.0 x 10^7 y sp act (WingJ58)	☢ EC(L) (HuiJ56) no EC(K), lim 0.06% (WingJ58) Δ -23.77 (MTW)	A chem, genet (HuiJ56) chem, mass spect (WingJ58) daughter Bi^{205} (HuiJ56)	γ Tl L X-rays	$Pb^{204}(n, \gamma)$ (WingJ58)
$\underline{Pb}^{206}$		% 25.1 (CollC52) 25.2 (WhiF56) 23.6 (NierA38) Δ -23.79 (MTW) σ_c 0.03 (GoldmDT64)			
$\underline{Pb}^{207}$		% 21.7 (WhiF56) 21.3 (CollC52) 22.6 (NierA38) Δ -22.45 (MTW) σ_c 0.72 (GoldmDT64)			

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{82}$Pb^{207m}	0.80 s (BendW55, HopN52, FariU58) 0.81 s (GlagV61) 0.82 s (LasJ51) others (CamE56, ReidJ54, IamP55, StelP55, VeeN56)	☢ IT (CamE50) Δ −20.81 (LHP, MTW)	A excit, sep isotopes (CamE50) chem, genet (FrieG53) daughter Bi^{207} (FrieG53, CamE56, MGowF53, WapA54b) daughter Po^{211m} (JentW54) not daughter Po^{211}, lim 0.005% (FrieG53)	γ 0.570 (98%), 1.064 (83%) e^- 0.482, 0.975, 1.048	daughter Bi^{207} (FrieG53) Pb^{207}(n, n'), Pb^{208}(n, 2n) (GlagV59) Pb^{208}(γ, n) (FariU58)
Pb^{208}		% 52.3 (CollC52, NierA38) 51.7 (WhiF56) Δ −21.75 (MTW) σ_c 0.0005 (GoldmDT64)			
Pb^{209}	3.30 h (WapA53 others (FajK41a, KriR42, MauW42, KriR40b)	☢ β^- (KriR40b, FajK41a) Δ −17.63 (MTW)	A chem (ThorRL37a, KriR40b) chem, sep isotopes (FajK41b) daughter Po^{213} (HageF47, HageF50, EnglA47, MeiW49, MeiW51) daughter Tl^{209} (EnglA47, HageF47)	β^- 0.635 max γ no γ	Pb^{208}(d, p) (RamlW59) descendant U^{233}, Th^{229}, Ac^{225} (HydE64) Pb^{208}(n, γ) (MauW42)
Pb^{210} (RaD)	20.4 y (HarbG59) 22.0 y (RamtH64) 22.8 y (ImrL63) 21.4 y (EckW60) 19.4 y (TobJ55b) 23.3 y (PatB59) others (CuriM31)	☢ β^-; α 1.7 x 10^{-6}% (KauP62) α 2 x 10^{-6}% (WolfGK64) others (NurM61) Δ −14.73 (MTW)	A chem, genet (CuriM31) daughter Tl^{210} (RaC'') daughter Po^{214} (RaC'), parent Bi^{210} (RaE); not parent Bi^{210m}, lim 10^{-4}% (LevyHB54) parent Hg^{206} (NurM61, KauP62, WolfGK64)	β^- 0.061 max e^- 0.030, 0.043 γ Bi L X-rays, 0.047 (4%) α 3.72 daughter radiations from Bi^{210}, Po^{210}	descendant Ra^{226} (HydE64)
Pb^{211} (AcB)	36.1 m (SargB39a, NurM65a) 36.0 m (CuriM31)	☢ β^- Δ −10.46 (MTW)	A chem, genet (CuriM31) daughter Po^{215} (AcA); parent Bi^{211} (AcC)	β^- 1.36 max γ 0.405 (3.4%), 0.427 (1.8%), 0.702 (0.4%), 0.766 (0.6%), 0.832 (3.4%) daughter radiations from Bi^{211}, Tl^{207}, Po^{211}	descendant Ac^{227} (HydE64)
Pb^{212} (ThB)	10.64 h (TobJ55a, MarinP53) others (ButtH52, CuriM31, DzhB55)	☢ β^- Δ −7.55 (MTW)	A chem, genet (CuriM31) daughter Po^{216} (ThA), parent Bi^{212} (ThC)	β^- 0.58 max e^- 0.148, 0.222 γ Bi X-rays, 0.239 (47%), 0.300 (3.2%) daughter radiations from Bi^{212}, Po^{212}, Tl^{208}	descendant Th^{228} (HydE64)
Pb^{213}	10.2 m (ButeF64a)	☢ β^- (ButeF64a) Δ −3 (MTW)	B chem, genet (ButeF64a) parent Bi^{213} (ButeF64a)	daughter radiations from Bi^{213}, Po^{213}, Pb^{209}, Tl^{209}	descendant Rn^{221} (ButeF64a)
Pb^{214} (RaB)	26.8 m (CuriM31)	☢ β^- (SargB33, RasF36) Δ −0.15 (MTW)	A chem, genet (CuriM31) daughter Po^{218} (RaA), parent Bi^{214} (RaC)	β^- 1.03 max (6%), 0.67 max e^- 0.037, 0.049 γ 0.053 (≈1%), 0.242 (4%), 0.295 (19%), 0.352 (36%) daughter radiations from Bi^{214}, Po^{214}	descendant Ra^{226} (HydE64)
$_{83}$Bi$^{\le 198}$	1.7 m (NeumH50a)	☢ α (TemD48)	E (TemD48) chem (NeumH50a)	α 6.2	deuterons on Pb (TemD48, NeumH50a)
Bi$^{197?}$	8.0 m (SiiA64) 7 m genet (NeumH50a)	☢ EC 99+%, α 0.05% (NeumH50a)	D chem (TemD48, NeumH50a) parent "25 m Pb" (NeumH50a) decay charac (SiiA64) formerly assigned to Bi^{198} (NeumH50a)	α 5.81	protons on Pb (TemD48, NeumH50a)
Bi^{199}	24.4 m (SiiA64) others (NeumH50a)	☢ EC 99+%, α ≈0.01% (NeumH50a, SiiA64) Δ −20 (MTW)	A chem (TemD48) chem, genet (NeumH50a, SiiA64) mass spect (SiiA64) ancestor Pb^{199} (NeumH50a) parent Pb^{199m} (SiiA64) possible existence of 2 isomers noted by SiiA64	γ Pb X-rays α 5.53 daughter radiations from Pb^{199}, Pb^{199m}	protons on Pb (NeumH50a, TemD48, SiiA64)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M–A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{83}$Bi^{200}	35 m genet (NeumH50a) others (VinA55)	☢ EC (NeumH50a) Δ -20 (MTW)	B chem, genet (NeumH50a) parent Pb^{200} (NeumH50a) daughter Po^{200} (KarrD51a)		protons on Pb (NeumH50a)
Bi^{201}	1.85 h (StocR56) others (NeumH50a, VinA55)	☢ EC (NeumH50) Δ -21 (MTW)	A chem, genet (NeumH50a) chem, mass spect (SiiA64) parent Pb^{201} (NeumH50a) parent Pb^{201m} (StocR56) daughter Po^{201} (?) (KarrD51a)	γ Pb X-rays daughter radiations from Pb^{201m}, Pb^{201}, Tl^{201}	protons on Pb (NeumH50a)
Bi^{201m}	52 m (SiiA64) others (NeumH50a, VinA55)	☢ α/KX-rays 0.02% (SiiA64) EC 99+%, α 0.003% (NeumH50a)	A chem, mass spect (SiiA64) chem, genet (NeumH50a) parent Pb^{201} (NeumH50a) daughter Po^{201} (SiiA64, KarrD51a)	γ Pb X-rays α 5.28 daughter radiations from Pb^{201}, Tl^{201}	protons on Pb, Bi (SiiA64, NeumH50a)
Bi^{202}	95 m (KarrD51) others (VinA55)	☢ EC (KarrD51) Δ -21 (MTW)	A chem, genet (KarrD51) daughter Po^{202} (KarrD51)	γ Pb X-rays, 0.422, 0.961	daughter Po^{202} (KarrD51)
Bi^{203}	11.8 h (StocR60a) others (StocR56, FritA58, NeumH50a)	☢ EC (NeumH50a) β^+ weak (NovaT58) no α, lim 6 x 10^{-7}% (NDS) α ≈10^{-5}% (DunlD52a) Δ -21.8 (MTW)	A chem, genet (NeumH50) parent Pb^{203} (NeumH50) parent Pb^{203m} (StocR56, FritA58) daughter Po^{203} (KarrD51) daughter At^{207} (BartoG51)	β^+ 1.35 max e^- 0.045, 0.098, 0.112, 0.176, 0.737 γ Pb X-rays, 0.186 (6%), 0.264 (6%), 0.381 (9%), 0.82 (78%, complex), 1.034 (16%), 1.52 (31%, complex), 1.87 (35%, doublet) daughter radiations from Pb^{203} daughter radiations from Pb^{203m} included in above listing	Pb^{206}(p, 4n) (NovaT58a, StocR60a)
Bi^{204}	11.2 h (StocR60a) 11.6 h (WerG56) 11.0 h (FritA58) others (StocR56, TemD47a)	☢ EC, no β^+ (TemD47a) no β^+, lim 0.07% (StocR58) Δ -21 (MTW)	A chem, sep isotopes, cross bomb, genet (TemD47a) parent Pb^{204m} (21%) (TemD47a, SunA50, KarrD51, StocR58) daughter Po^{204} (KarrD51)	γ Pb X-rays, 0.21 (complex), 0.375, 0.671, 0.91 (complex), 0.98, 1.21 (complex), many others e^- 0.063, 0.075, 0.087, 0.128, 0.133, 0.161, 0.201, 0.287, 0.360, 0.583, 0.811, 0.824, 0.897, many others daughter radiations from Pb^{204m} included in above listing	Pb^{206}(p, 3n) (StocR60a) Tl^{203}(α, 3n) (StocR58) Pb^{204}(d, 2n) (TemD47a, SunA50)
Bi^{205}	15.31 d (BrunnJ61) others (FritA58, KarrD51, VinA55)	☢ EC (KarrD51) β^+ 0.06% (PerdC62) Δ -21.07 (MTW)	A chem, genet, sep isotopes (KarrD51) daughter Po^{205} (KarrD51) daughter At^{209} (BartoG51) parent Pb^{205} (HuiJ56)	β^+ 0.98 max e^- 0.011, 0.023, others γ Pb X-rays, 0.26 (3%, complex), 0.51 (4%, complex), 0.57 (14%, complex), 0.703 (28%), 0.911 (4%), 0.988 (17%), 1.044 (8%), 1.615 (4%), 1.766 (27%), 1.864 (6%), 1.906 (2%)	Pb^{206}(d, 3n) (HerrlC61, StocR60, BergI62, BonaE62) Bi^{209}(p, 5n) Po^{205}(EC) (BonaE62)
Bi^{206}	6.243 d (BrunnJ61) others (ArbE57, AlbuD51, KriR40b)	☢ EC (LutA44, AlbuD51) β^+ 8 x 10^{-4}% (PerdC62) Δ -20.18 (MTW)	A chem, sep isotopes (FajK41b, TemD47a) genet energy levels (AlbuD54a, StelP55b) daughter Po^{206} (TemD47) daughter At^{210} (NeumH50b)	γ Pb X-rays, 0.184 (21%), 0.343 (26%), 0.398 (10%), 0.497 (18%), 0.516 (46%), 0.538 (34%), 0.803 (99%), 0.880 (72%), 0.895 (19%), 1.019 (8%), 1.099 (13%), 1.596 (8%), 1.720 (36%) e^- 0.096, 0.168, 0.255	Pb^{206}(d, 2n) (FajK41b, WieR63)
Bi^{207}	30.2 y (HarbG59) 28 y (SosJ59) 38 y (AppE61) others (AlbuD55, NeumH51)	☢ EC (GermL50, NeumH51) Δ -20.04 (MTW)	A chem, genet (MGowF53a) daughter At^{211} (NeumH51) parent Pb^{207m} (MGowF53, FrieG53, WapA54b, CamE56)	γ Pb X-rays, 0.570 (98%), 1.063 (77%), 1.771 (9%) e^- 0.482, 0.975, 1.048 daughter radiations from Pb^{207m} included in above listing	Pb(d, xn), daughter At^{211} (HydE64)
Bi^{208}	3.68 x 10^5 y sp act, mass spect (HalpJ64) others (RoyJ58, MillC59)	☢ EC, no β^+ lim 0.3% (MillC59) Δ -18.88 (MTW)	B chem (NeumH51) excit, genet energy levels (RoyJ58, MillC59)	γ Pb X-rays, 2.614 (100%)	Bi^{209}(n, 2n) (RoyJ58, HalpJ64)
Bi^{209}	>2 x 10^{18} y sp act (HinE58) 2 x 10^{17} y sp act (RieW52, PorsW56) others (FaraH51a)	☢ no α (HinE58) α (FaraH51, PorsW56) % 100 (NierA38) Δ -18.26 (MTW) σ_c 0.015 (to Bi^{210}) 0.019 (to Bi^{210m}) (GoldmDT64)		α ? 3.0	

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{83}$Bi^{210} (RaE)	5.013 d (RobeJ56) others (LocE53, BegF52, SiegK47, CuriM31, HoleN45, TemD47a, SerL47b, LivJ36, CorkJ40, HurD40)	☢ β^- 99+%, α 1.3 x 10^{-4}% (KauP62) others (NurM61, BrodE47) Δ -14.79 (MTW)	A chem, genet (CuriM31) daughter Pb^{210} (RaD), parent Po^{210} (RaF); parent Tl^{206} (BrodE47)	β^- 1.160 max α 4.69 (5 x 10^{-5}%), 4.65 (7 x 10^{-5}%) γ Po X-rays (weak)	Bi^{209}(n, γ) (SiegK47b) descendant Ra^{226} (HydE64)
Bi^{210m}	≈2.6 x 10^{6} y yield (HugD53)	☢ α 99.6%, β^- 0.4% (LevyHB54) Δ -14.52 (LHP, MTW)	A chem, genet (NeumH50) chem, mass spect (LevyHB54) parent Po^{210} (RaF) (0.4%), parent Tl^{206} (99.6%) (LevyHB54) not daughter Pb^{210}, lim 10^{-4}% (LevyHB54) others (NeumH50)	α 4.96 (58%), 4.92 (36%), 4.57 (6%) γ 0.262 (45%), 0.30 (23%), 0.34, 0.61 daughter radiations from Tl^{206}	Bi^{209}(n, γ) (NeumH50)
Bi^{211} (AcC)	2.16 m (CuriM31) 2.15 m (SpiesF54) 2.13 m (NurM65a)	☢ α 99+%, β^- 0.27% (NurM65a) α 99+%, β^- 0.29% (GiaM62a) Δ -11.84 (MTW)	A chem, genet (CuriM31) daughter Pb^{211} (AcB), parent Po^{211} (AcC'), parent Tl^{207} (AcC"); daughter At^{215} (KarlB44)	α 6.62 (84%), 6.28 (16%) γ 0.351 (14%) e$^-$ 0.265 daughter radiations from Tl^{207}, Po^{211}	descendant Ac^{227} (HydE64)
Bi^{212} (ThC)	60.60 m (A[illegible]K61) 60.5 m (CuriM31)	☢ β^- 64.0%, α 36.0% (WalkJ65) β^- 64.2%, α 35.8% (BertG62, BertG60) others (SchupG60, BarkS61, RiceP58a, SenF56, MarinP53, FlaF62, ProsD58, FerrJ61, KovAF38) Δ -8.13 (MTW)	A chem, genet (CuriM31) daughter Pb^{212} (ThB), parent Po^{212} (ThC') and Tl^{208} (ThC"); daughter At^{216} (KarlB43a, GhiA48, MeiW51)	β^- 2.25 max e$^-$ 0.025, 0.036 α 6.09 (10%), 6.05 (25%) γ Tl X-rays, 0.040 (2%), 0.288 (0.5%), 0.46 (0.8%, complex), 0.727 (7%), 0.785 (1.1%), 1.620 (1.8%) daughter radiations from Tl^{208}, Po^{212}	descendant Th^{228} (HydE64)
Bi^{213}	47 m (HageF47) 46 m (EnglA47)	☢ β^- 97.8%, α 2.2% (GraeG64, ValliK64) Δ -5.24 (MTW)	A chem, genet (EnglA47, HageF47) daughter At^{217}, parent Po^{213} (HageF47, EnglA47, HageF50) parent Tl^{209} (HageF50a, HageF47, EnglA47) daughter Pb^{213} (ButeF64a)	β^- 1.39 max γ 0.437 α 5.87 daughter radiations from Po^{213}, Pb^{209}, Tl^{209}	descendant U^{233}, Th^{229}, Ac^{225} (HydE64)
Bi^{214} (RaC)	19.7 m (CuriM31) 19.9 m (DaniH56)	☢ β^- 99+% (CuriM31) α 0.021% (WaleR60) Δ -1.19 (MTW)	A chem, genet (CuriM31) daughter Pb^{214} (RaB), daughter At^{218}, parent Po^{214} (RaC'), parent Tl^{210} (RaC"); descendant Fr^{222} (HydE50a, HydE51a)	β^- 3.26 max γ 0.609 (47%), 0.769 (5%), 0.935 (3%), 1.120 (17%), 1.238 (6%), 1.378 (5%), 1.40 (4%, complex), 1.509 (2%), 1.728 (3%), 1.764 (17%), 1.848 (2%), 2.117 (1%), 2.204 (5%), 2.445 (2%) α 5.51 (0.008%), 5.45 (0.012%) daughter radiations from Po^{214}	descendant Ra^{226} (HydE64)
Bi^{215}	7 m (NurM65a) 8 m (HydE53)	☢ β^- (HydE53) Δ 1.7 (MTW)	A chem, genet (HydE53) daughter At^{219}, parent Po^{215} (AcA) (HydE53)	daughter radiations from Po^{215}, Po^{211}	descendant Ac^{227}, natural source (HydE53, HydE64)
$_{84}$Po^{193}	short (SiiA65b)	☢ α (SiiA65b)	E excit, decay charac (SiiA65b)	α 7.0	F^{19} on Re (SiiA65b)
Po^{194}	0.5 s (SiiA65b) others (TovP58)	☢ α (SiiA65b)	B excit, decay charac (SiiA65b)	α 6.85	F^{19} on Re (SiiA65b)
Po^{195}	3 s (SiiA65b) others (TovP58)	☢ α (SiiA65b)	B excit, decay charac (SiiA65b)	α 6.63	F^{19} on Re (SiiA65b)
Po^{195m}	1.4 s (SiiA65b)	☢ α (SiiA65b)	B excit, decay charac (SiiA65b)	α 6.72	F^{19} on Re (SiiA65b)
Po^{196}	6 s (SiiA65b) 4 s (TovP58)	☢ α (SiiA65b, TovP58)	B excit, decay charac (TovP58, SiiA65b) formerly assigned to Po^{193} (TovP58)	α 6.53	Bi^{209}(p, 14n) (TovP58) F^{19} on Re (SiiA65b)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12} \equiv 0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{84}\mathrm{Po}^{197}$	54 s (SiiA65b) 58 s (BrunC65a)	☢ α (SiiA65b, BrunC65a)	B excit (SiiA65b) chem (BrunC65a)	α 6.30	F^{19} on Re (SiiA65b) Bi^{209}(p, 13n) (BrunC65a)
Po^{197m}	25 s (SiiA65b) 29 s (BrunC65a) others (TovP58, AttH59a)	☢ α (SiiA65b, BrunC65a)	B decay charac (TovP58) chem (AttH59a, BrunC65a) excit (SiiA65b)	α 6.39	Bi^{209}(p, 13n) (BrunC65a, TovP58) F^{19} on Re (SiiA65b) $Ne^{20, 22}$ on W (AttH59a)
Po^{198}	1.7 m (SiiA65b, BrunC65a, BrunC64) 1.8 m (AttH59a, AttH59) others (AttH56)	☢ α >34% (BrunC65a)	B chem (AttH56, AttH59a) excit (SiiA65b) chem, genet (BrunC65a) ancestor Tl^{198} (BrunC65a) formerly assigned to Po^{196} (AttH56, AttH59a, AttH59, BrunC64)	α 6.16	Bi^{209}(p, 12n) (BrunC65a) C^{12} on Pt (AttH59) F^{19} on Re (SiiA65b) $Ne^{20, 22}$ on W (AttH59a)
Po^{199}	5.0 m (TieE65) 5.2 m (BrunC65a) others (RosS54b, AttH59, BrunC64)	☢ EC 97.3%, α 2.7% (BrunC65a)	A chem (RosS54b) chem, mass spect (TieE65) chem, genet (BrunC65a) ancestor Tl^{199} (BrunC65a) formerly assigned to Po^{198} (RosS54b, AttH59, BrunC64)	α 5.94	Bi^{209}(p, 11n) (BrunC65a, TieE65)
Po^{199m}	4.2 m (SiiA65b) 4.1 m (TieE65, BrunC65a) others (RosS54b, AttH59, AttH59a, BrunC64)	☢ EC 74%, α 26% (BrunC65a)	A chem (RosS54b) excit (SiiA65b) chem, mass spect (TieE65) chem, genet (BrunC65a) ancestor Tl^{199} (BrunC65a) formerly assigned to Po^{197} (RosS54, AttH59, AttH59a, BrunC64)	α 6.05	Bi^{209}(p, 11n) (TieE65, BrunC65a) F^{19} on Re (SiiA65b)
Po^{200}	10.5 m (HoffR63) 11.4 m (SiiA65b, TieE65, BrunC65, BrunC65a) others (KarrD51a, AttH59, ForW61a, RosS54b, BrunC64)	☢ EC 88%, α 12% (BrunC65a) Δ −16 (MTW)	A chem (KarrD51a) chem, mass spect (ForW61a, TieE65) parent Bi^{200} (KarrD51a) daughter At^{200} (HoffR63) ancestor Tl^{200} (BrunC65a) formerly assigned to Po^{199} (RosS54b, AttH59, ForW61a, BelyB61, BelyB62, BrunC64)	α 5.86	C^{12} on Pt (ForW61a, AttH59, BrunC65) $Au^{197}(C^{12}, 9n)At^{200}$(EC) (HoffR63) Bi^{209}(p, 10n) (BrunC64, BrunC65, TieE65)
Po^{201}	15.1 m (TieE65) 15 m (HoffR63) others (ForW61a, BelyB61, AttH59, BrunC65a, BrunC65, KarrD51a, BrunC64)	☢ EC 98.9%, α 1.1% (BrunC65a) EC 99.2%, α 0.8% (BelyB61, BelyB62) Δ −16 (MTW)	A chem, genet (KarrD51a, SiiA64) chem, mass spect (ForW61a, TieE65) parent Bi^{201m} (SiiA64, KarrD51a) parent Bi^{201} (?) (KarrD51a) daughter At^{201} (HoffR63) ancestor Tl^{201} (BrunC65a)	α 5.68 daughter radiations from Bi^{201m}	Bi^{209}(p, 9n) (BrunC64, BrunC65a, TieE65) C^{12} on Pt (AttH59, ForW61a) daughter At^{201} (HoffR63)
Po^{201m}	8.9 m (TieE65) 9 m (HoffR63, BrunC65a, BrunC65) others (BrunC65, RosS54b)	☢ α 3%, EC 97% (BrunC65a) α (RosS54b, HoffR63)	A chem (RosS54b) excit, decay charac (HoffR63) chem, mass spect (TieE65) ancestor Tl^{201} (BrunC65a) formerly assigned to Po^{200} (RosS54b, AttH59, ForW61a, BelyB61, BrunC64)	α 5.78	B^{209}(p, 9n) (TieE65, BrunC65a) C^{12} on Pt (BrunC65)
Po^{202}	45 m (BelyB61, HoffR63, TieE65) others (StonA57, RosS54b, BurcW54, AttH59, ForW61a, BrunC64, BrunC65, BrunC65a)	☢ EC 98%, α 2% (StonA57) Δ −18 (MTW)	A chem, genet, excit (KarrD51) chem, genet, mass spect (ForW61a, ForW61) parent Bi^{202} (KarrD51) daughter At^{202} (ForW61, HoffR63) daughter Rn^{206} (StonA57, MomF55a)	α 5.58 daughter radiations from Bi^{202}, Pb^{198}	Bi^{209}(p, 8n) (B.unC64, BrunC65a) C^{12} on Pt (ForW61a, BrunC65) $Au^{197}(C^{12}, 7n)At^{202}$(EC) (ForW61, HoffR63)
Po^{203}	42 m (BellRE56) 47 m (KarrD51)	☢ EC 99+%, α 0.02% (BelyB62, BelyB61) Δ −17 (MTW)	A chem, genet (ForW61, KarrD51) parent Bi^{203} (KarrD51) daughter At^{203} (ForW61)	α 5.49 daughter radiations from Bi^{203}	Bi^{209}(p, 7n) (BellRE56, KarrD51) $Au^{197}(C^{12}, 6n)At^{203}$(EC) (ForW61)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{84}$Po^{204}	3.6 h (ForW61a) others (BelyB61, KarrD51, RosS54b, BurcW56)	☢ EC 99+%, α 0.6% (BelyB63) Δ −18 (MTW)	A chem, genet (KarrD51) daughter Rn^{208} (MomF55a) parent Bi^{204}, parent Pb^{200} (KarrD51) daughter At^{204} (ThorP64)	α 5.38 daughter radiations from Bi^{204}	Bi^{209}(p, 6n) (AxeS61) Au^{197}(C^{12}, 5n) At^{204}(EC) (HoffR63, ForW61, LatR61, ThorP64) Pt^{196}(C^{12}, 4n) (AttH59, ForW61a) alphas on Pb (KarrD51)
Po^{205}	1.8 h (BellRE56) others (KarrD51)	☢ EC 99+%, α 0.07% (HallK51) Δ −18 (MTW)	A chem, genet, sep isotopes, excit (KarrD51) chem, mass spect (ForW61a) parent Bi^{205}, parent Pb^{201} (KarrD51) daughter At^{205} (BartoG51)	α 5.25	Bi^{209}(p, 5n) (BellRE56, AxeS61) Pb^{204}(α, 3n) (KarrD51)
Po^{206}	8.8 d (ArbE57, JohnW56) others (TemD47, BarabS57, BurcW54)	☢ EC 95%, α 5% (MomF55a) no β^{+}, lim 0.1% (ArbE57) others (TemD47) Δ −18.33 (MTW)	A chem, genet, sep isotopes (TemD47) chem, mass spect (ForW61a) parent Bi^{206} (TemD47) daughter Rn^{210} (MomF55a, MomF52) daughter At^{206} (ThorP64)	γ Bi X-rays, 0.286 (↑ 35), 0.338 (↑ 40), 0.51 (↑ 100, complex), 0.807 (↑ 60), 1.02 (↑ 85, complex) e^{-} 0.045, 0.196, 0.248 α 5.22 (5%) daughter radiations from Bi^{206}	Bi^{209}(p, 4n) (AxeS61) Pb^{204}(α, 2n) (TemD47) Pb^{206}(α, 4n) (JohnW56)
Po^{207}	5.7 h (BellRE56, TemD47) 6.2 h (JohnW56)	☢ EC 99+%, α ≈0.01% (TemD47) β^{+} 0.5% (ArbE58a) Δ −17.14 (MTW)	A chem, excit, sep isotopes (TemD47) chem, genet (StonA56) daughter Rn^{211} (StonA56) daughter At^{207} (BartoG51)	γ Pb X-rays, 0.25 (↑ 5), 0.35 (↑ 4), 0.41 (↑ 13), 0.74 (↑ 36), 0.95 (↑ 84), 1.15 (↑ 6), 1.37 (↑ 4), 2.06 (↑ 1.6), others, all γ rays complex e^{-} 0.159, 0.255, 0.315, 0.652, 0.902, many others β^{+} 1.14 max α 5.11	Bi^{209}(p, 3n) (BellRE56) Pb^{206}(α, 3n) (JohnW56)
Po^{207m}	2.8 s (HargC62)	☢ IT (HargC62) Δ −15.75 (LHP, MTW)	B excit, critical abs (HargC62)	γ Po X-rays, 0.26 (42%), 0.31 (40%), 0.82 (100%) e^{-} 0.22, 0.24	Bi^{209}(p, 3n) (HargC62)
Po^{208}	2.93 y (TemD50)	☢ α (TemD47) EC ≈0.006% (AsaF57a) Δ −17.47 (MTW)	A chem, excit, sep isotopes (TemD47) chem, mass spect (ForW61) daughter Rn^{212}, daughter At^{208} (HydE50, MomF52)	α 5.11 γ Bi X-rays, 0.285 (0.003%), 0.60 (0.006%, complex)	Bi^{209}(d, 3n) (RamlW59) Bi^{209}(p, 2n) (AndrC56)
Po^{209}	103 y sp act (AndrC56)	☢ α 99+%, EC ≈0.5% (PerlmI50, AsaF57a) Δ −16.37 (MTW)	A chem, excit (KellE49) daughter At^{209} (BartoG51)	α 4.88 (99%) γ Bi X-rays, 0.261 (0.4%, complex), 0.91 (0.5%) e^{-} 0.173	Bi^{209}(d, 2n) (RamlW59) Bi^{209}(p, n) (AndrC56)
Po^{210} (RaF)	138.40 d (EicJ54) others (CurtM53, GinD53, BeamW49, TemD47, HurD40, CorkJ40, CuriM31)	☢ α; β stable (cons energy) (ForB58) Δ −15.95 (MTW) σ$_{c}$ <0.03 (to Po^{211}) <0.0005 (to Po^{211m}) (GoldmDT64)	A chem, genet (CuriM31) daughter Bi^{210} (RaE); daughter Bi^{210m} (0.4%) (LevyH54) daughter At^{210} (KellE49, BartoG51)	α 5.305 (100%) γ 0.803 (0.0011%)	daughter Bi^{210} from natural source or Bi^{209}(n, γ) Bi^{210}(β^{-}) (HydE64)
Po^{211} (AcC′)	0.52 s (SpiesF54, LeiR51) others (TovP58, WinnM54a)	☢ α; β stable (cons energy) (ForB58) Δ −12.43 (MTW)	A genet (CuriM31) daughter Bi^{211} (AcC); daughter At^{211} (CorsD40, CorsD40a) daughter Rn^{215} (MeiW52) not parent Pb^{207m}, lim 0.005% (FrieG53) not daughter Po^{211m}, lim 1% (JentW54)	α 7.45 (99%) γ 0.570 (0.5%), 0.90 (0.5%)	descendant Ac^{227} (HydE64)
Po^{211m}	25 s (JentW54, SpiesF54, KarnV62) others (WinnM54a)	☢ α (SpiesF54) Δ −11.00 (LHP, MTW)	A chem, excit (SpiesF54) genet energy levels (JentW54) parent Pb^{207m} (JentW54) not parent Po^{211}, lim 1% (JentW54) not daughter At^{211}, lim 0.01% (SpiesF54)	α 8.88 (7%), 7.28 (91%) γ 0.570 (92%), 1.063 (77%) e^{-} [0.482, 0.975, 1.048]	Pb^{208}(α, n) (SpiesF54) Bi^{209}(α, pn) (PerlmI62)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{84}Po^{212}$ (ThC')	3.04×10^{-7} s delay coinc (BunyD49) others (FlaF62, HillJ48, JelJ48, VNamF49, DunwJ39, BradH43, HayaT53)	☢ α; β stable (cons energy) (ForB58) Δ −10.37 (MTW)	A genet (CuriM31) daughter Bi^{212} (ThC); daughter Rn^{216} (MeiW49, MeiW51)	α 8.78 (100%); also long range α's following decay of Bi^{212} parent	descendant Th^{228} (HydE64)
Po^{212m}	45 s (PerlmI62) others (KarnV62)	☢ α, no IT, lim 1.5% (PerlmI62) Δ −7.44 (LHP, MTW)	A chem, cross bomb, genet energy levels (PerlmI62)	α 11.65 (97%) γ 0.57 (2%), 2.61 (2.6%)	$Bi^{209}(\alpha, p)$, $Pb^{208}(B^{11}, Li^7)$ (PerlmI62)
Po^{213}	4.2×10^{-6} s delay coinc (JelJ48)	☢ α (HageF47, EnglA47) Δ −6.66 (MTW)	A genet (HageF47, EnglA47) daughter Bi^{213}, parent Pb^{209} (HageF47, EnglA47, HageF50) daughter Rn^{217}, parent Pb^{209} (MeiW49, MeiW51)	α 8.38	daughter Bi^{213} (HydE64)
Po^{214} (RaC')	1.64×10^{-4} s delay coinc (DobT61, DarG50) others (OgiK60, BallR53, DunwJ39, RotJ41a, WardAG42, JacoJ43, LunA47, BunyD48, RowS47)	☢ α; β stable (cons energy) (ForB58) Δ −4.47 (MTW)	A genet (CuriM31) daughter Bi^{214} (RaC), parent Pb^{210} (RaD) daughter Rn^{218} (StuM48)	α 7.69 (100%); also long range α's, principally 9.06 (0.0022%), following decay of Bi^{214} parent γ 0.799 (0.014%)	descendant Ra^{226}, from natural source descendant U^{230} (HydE64)
Po^{215} (AcA)	1.778×10^{-3} s delay coinc (VolY61) others (WardAG42)	☢ α 99+%, β^- 0.00023% (AviP50) α 99+%, β^- 0.0005% (KarlB44) Δ −0.52 (MTW)	A genet (CuriM31) daughter Rn^{219} (An), parent Pb^{211} (AcB); parent At^{215} (KarlB44) daughter Bi^{215} (HydE53)	α 7.38 (100%) daughter radiations from Pb^{211}, etc.	descendant Ac^{227}, from $Ra^{226}(n, \gamma)Ra^{227}(\beta^-)$, or natural source (HydE64)
Po^{216} (ThA)	0.145 s (DiaH63) others (WardAG42;	☢ α; β stable (cons energy) (ForB58) others (KarlB43a) Δ 1.78 (MTW)	A genet (CuriM31) daughter Rn^{220} (Tn), parent Pb^{212} (ThB)	α 6.78 (100%) daughter radiations from Pb^{212}, etc.	descendant Th^{228} (HydE64)
Po^{217}	<10 s (MomF56)	☢ α (MomF56) no β^-, lim 0.1% (ValliK64) Δ 6 (MTW)	B genet (MomF56) daughter Rn^{221} (MomF56, MomF52)	α 6.55	daughter Rn^{221} (MomF52)
Po^{218} (RaA)	3.05 m (CuriM31)	☢ α 99+%, β^- 0.0185% (WaleR59a) others (HieF52) Δ 8.38 (MTW)	A chem, genet (CuriM31) daughter Rn^{222} (Rn), parent Pb^{214} (RaB); parent At^{218} (KarlB43)	α 6.00 (100%) daughter radiations from Pb^{214}, Bi^{214}, Po^{214}	descendant Ra^{226}, from natural source (HydE64)
$_{85}At^{200}$	0.9 m (HoffR63) others (BartoG51)	☢ α (HoffR63) α, EC (BartoG51)	B chem, excit (BartoG51) chem, excit, genet (HoffR63) parent Po^{200} (HoffR63)	α 6.47, 6.42	$Au^{197}(C^{12}, 9n)$ (HoffR63)
At^{201}	1.5 m (HoffR63) others (BartoG51)	☢ α, EC (HoffR63)	A chem, excit, genet (HoffR63) parent Po^{201} (HoffR63) daughter Fr^{205} (GrifR64)	α 6.35 daughter radiations from Bi^{197}, Po^{201}	$Au^{197}(C^{12}, 8n)$ (ThomT62)
At^{202}	3.0 m (LatR61, HoffR63) others (ForW61)	☢ EC 88%, α 12% (LatR61) Δ −10 (MTW)	A chem, mass spect (ForW61) chem, excit, genet (HoffR63) parent Po^{202} (ForW61, HoffR63)	α 6.23 (4.3%), 6.12 (7.7%) daughter radiations from [Bi^{198}], Po^{202}	$Au^{197}(C^{12}, 7n)$ (ThomT62)
At^{203}	7.4 m (LatR61, HoffR63) others (ForW61, BartoG51, BurcW56)	☢ EC 86%, α 14% (LatR61) Δ −11 (MTW)	A chem, excit (BartoG51, MillJF50) chem, mass spect (ForW61) parent Po^{203} (ForW61)	α 6.09 daughter radiations from Po^{203}, Bi^{199}, etc.	$Au^{197}(C^{12}, 6n)$ (ThomT62)
At^{204}	9.3 m (LatR61, HoffR63) 8.9 m genet (ThorP64) others (ForW61)	☢ EC 95.5%, α 4.52% (LatR61) Δ −11 (MTW)	A chem, mass spect (ForW61) chem, genet (ThorP64) chem, excit (HoffR63) parent Po^{204} (ThorP64)	α 5.95 [daughter radiations from Po^{204}, Bi^{200}]	$Au^{197}(C^{12}, 5n)$ (HoffR63, ForW61, LatR61) $Bi^{209}(\alpha, 9n)$ (ThorP64)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{85}$At^{204}	≈25 m genet (BartoG51)	☢ EC (BartoG51)	G chem, excit, genet (BartoG51) activity not observed (ThorP64, LatR61)		alphas on Bi^{209} (BartoG51)
At^{205}	26.2 m (HoffR63, LatR61) others (BartoG51, BurcW54, ForW61, BurcW56)	☢ EC 82%, α 18% (LatR61) Δ −13 (MTW)	A chem, mass spect (ForW61) chem, excit, genet (BartoG51, MillJF50) parent Po^{205} (BartoG51) daughter Fr^{209} (GrifR64)	α 5.90 daughter radiations from Po^{205}, Bi^{201}, Pb^{201}, Pb^{201m}, Tl^{201}	Au^{197}(C^{12}, 4n) (ThomT62) Bi^{209}(α, 8n) (BartoG51) Au^{197}(N^{14}, 6n)[Rn^{205}] (EC) (HoffR63, ForW61)
At^{206}	32.8 m (ThorP64) 29.5 m (LatR61) 31 m (HoffR63)	☢ α ≈88%, EC ≈12% (LatR61) Δ −12 (MTW)	A chem, mass spect (ForW61) chem, genet (ThorP64) parent Po^{206} (ThorP64)	α 5.70 (88%) γ Bi X-rays, Po X-rays, 0.068 (10%) e^- 0.052, 0.064 daughter radiations from Bi^{202}, Po^{206}	Au^{197}(C^{12}, 3n) (ForW61, LatR61, HoffR63) Au^{197}(N^{14}, 5n)Rn^{206}(EC) (HoffR63) Bi^{209}(α, 7n) (ThorP64)
At^{206}	2.9 h (StonA56) 2.6 h (BartoG51)	☢ EC (BartoG51)	G chem, excit, genet (BartoG51) activity not observed (ThorP64)		alphas on Bi (BartoG51)
At^{207}	1.8 h (BurcW54, StonA57, ForW61) 2.0 h (BartoG51)	☢ EC ≈90%, α ≈10% (BartoG51, TemD48a) Δ −13.41 (LHP, MTW)	A chem, excit, genet (TemD48a, BartoG51) parent Po^{207}, parent Bi^{203} (BartoG51) daughter Rn^{207} (BurcW54, StonA57) daughter Fr^{211} (GrifR64)	α 5.76 daughter radiations from Po^{207}, Bi^{203}, Pb^{203}	Bi^{209}(α, 6n) (TemD48a, BartoG51) Au^{197}(N^{14}, 4n)Rn^{207}(EC) (HoffR63)
At^{208}	1.6 h (StonA56, ForW61) 1.7 h (BartoG51)	☢ EC 99+%, α 0.5% (HydE50) Δ −12 (MTW)	A chem, genet (HydE50, ThorP64) chem, mass spect (ForW61) daughter Fr^{212}, parent Po^{208} (HydE50, MomF52)	γ Po X-rays, 0.18 (25%), 0.25, 0.66 (100%) α 5.65 daughter radiations from Bi^{204}	Bi^{209}(α, 5n) (ThorP64)
At^{208}	6.3 h genet (BartoG51)	☢ EC (BartoG51)	G chem, excit, genet (BartoG51) activity not observed (ThorP64)		alphas on Bi^{209} (BartoG51)
At^{209}	5.5 h (ForW61, BartoG51)	☢ EC ≈95%, α ≈5% (BartoG51) Δ −12.89 (MTW)	A chem, genet, excit (BartoG51) chem, mass spect (ForW61) parent Po^{209}, parent Bi^{205} (BartoG51) daughter Rn^{209} (MomF52, MomF55a) daughter Fr^{213} (GrifR64)	γ Po K X-rays, 0.195 (23%), 0.545 (62%), 0.780 (94%) e^- 0.076, 0.102, 0.178, 0.451, 0.686 α 5.65 (5%)	Bi^{209}(α, 4n) (RamlW59)
At^{210}	8.3 h (KellE49)	☢ EC 99+%. α 0.17% (HoffR53) Δ −12.12 (MTW)	A chem, genet, excit (KellE49) parent Po^{210} (RaF) (KellE49, BartoG51) parent Bi^{206} (NeumH50b)	γ Po X-rays, 0.245 (79%), 1.180 (100%), 1.436 (29%), 1.483 (48%), 1.599 (14%) e^- 0.023, 0.031, 0.043, 0.152, 0.229 α 5.52 (0.05%), 5.44 (0.05%), 5.36 (0.06%)	Bi^{209}(α, 3n) (RamlW59)
At^{211}	7.21 h (AppE61) others (GrayP56, CorsD40, KellE49, CrofP64)	☢ α 40.9%, EC 59.1% (NeumH51) Δ −11.64 (MTW)	A chem, excit, genet (CorsD40, KellE49) parent Bi^{207} (NeumH51) daughter Rn^{211} (MomF55a, MomF52) parent Po^{211} (AcC$'$) (CorsD40, CorsD40a) not parent Po^{211m}, lim 0.01% (SpiesF54)	α 5.868 γ Po X-rays, 0.67 (weak) daughter radiations from Po^{211}	Bi^{209}(α, 2n) (RamlW59)
At^{212}	0.30 s (JonWB63) others (RitJ62, WinnM54a)	☢ α (JonWB63) EC unstable (cons energy) (MTW) Δ −8.64 (MTW)	B excit, decay charac (JonWB63)	α 7.66 (80%), 7.60 (20%) e^- 0.047, 0.059	Bi^{209}(α, n) (JonWB63)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns		Class; Identification; Genetic relationships		Major radiations: approximate energies (MeV) and intensities		Principal means of production
$_{85}$At^{212m}	0.12 s (JonWB63) others (RitJ62)	☢	α, no IT, lim 1% (JonWB63) β^-, EC unstable (cons energy) (MTW)	B	excit, decay charac (JonWB63)	α	7.88 (20%), 7.82 (80%)	Bi^{209}(α, n) (JonWB63)
		Δ	−8.42 (LHP, MTW)			e^-	0.047, 0.059	
At^{213}	[short] (KeyJ51)	☢	α (KeyJ51)	E	genet, decay charac (KeyJ51)	α	9.2	descendant Pa^{225} (KeyJ51)
		Δ	−6.5 (MTW)		descendant Pa^{225} (KeyJ51)			
At^{214}	$\approx 2 \times 10^{-6}$ s est (MeiW51)	☢	α (MeiW49) EC unstable (cons energy) (MTW)	B	genet (MeiW49) daughter Fr^{218} (MeiW49, MeiW51)	α	8.78 (99%)	descendant Pa^{226} (MeiW49, MeiW51)
		Δ	−3.42 (MTW)					
At^{215}	$\approx 10^{-4}$ s delay coinc (GhiA48, MeiW51)	☢	α (KarlB44, GhiA48)	A	genet (KarlB44, GhiA48) daughter Fr^{219}, parent Bi^{211} (AcC) (GhiA48, MeiW51, MeiW49) daughter Po^{215} (AcA), parent Bi^{211} (AcC) (KarlB44)	α	8.01 daughter radiations from Bi^{211}, etc.	descendant Pa^{227} (HydE64)
		Δ	−1.25 (MTW)					
At^{216}	$\approx 3 \times 10^{-4}$ s delay coinc (MeiW49, MeiW51)	☢	α (KarlB43a, GhiA48) β^-, EC unstable (cons energy) (MTW)	A	genet (GhiA48) daughter Fr^{220}, parent Bi^{212} (ThC) (GhiA48, MeiW51) parent Bi^{212} (ThC) (KarlB43a)	α	7.80 (97%)	descendant Pa^{228} (HydE64)
		Δ	2.25 (MTW)					
At^{217}	0.0323 s delay coinc (DiaH63) others (HageF47, HageF50, EnglA47)	☢	α (EnglA47, HageF47) β^- unstable (cons energy) (MTW)	A	genet (EnglA47, HageF47) daughter Fr^{221}, parent Bi^{213} (EnglA47, HageF47, HageF50, CranT48)	α	7.07 (99+%) daughter radiations from Bi^{213}, etc	descendant Ac^{225} (EnglA47, HageF47)
		Δ	4.38 (MTW)					
At^{218}	1.5–2.0 s (WaleR48) others (KarlB43)	☢	α (KarlB43) α 99+%, β^- 0.1% (WaleR48)	B	genet (KarlB43, WaleR59a) daughter Po^{218} (RaA), parent Bi^{214} (RaC) (KarlB43, WaleR48, WaleR59a)	α	6.70 (94%), 6.65 (6%) daughter radiations from Rn^{218}, Bi^{214}, etc	daughter Po^{218} (KarlB43, WaleR48)
		Δ	8.11 (MTW)					
At^{219}	0.9 m (HydE53)	☢	α ≈97%, β^- ≈3% (HydE53)	B	chem, genet (HydE53) daughter Fr^{223} (AcK), parent Rn^{219} (An), parent Bi^{215} (HydE53)	α	6.28 daughter radiations from Bi^{215}, Rn^{219}, etc.	descendant Ac^{227}, natural source (HydE53)
		Δ	10.5 (MTW)					
$_{86}$Rn$^{<202}$	short (NurM66)	☢	α (NurM66)	F	excit (NurM66)	α	6.90	O^{16} on Pt, N^{14} on Au, C^{12} on Hg (NurM66)
Rn$^{<202}$	1 s (NurM66)	☢	α (NurM66)	F	excit (NurM66)	α	6.85	O^{16} on Pt, N^{14} on Au, C^{12} on Hg (NurM66)
Rn$^{201?}$	3 s (NurM66)	☢	α (NurM66)	E	cross bomb, excit (NurM66)	α	6.77	Au^{197}(N^{14}, 10n), O^{16} on Pt (NurM66)
Rn$^{<202}$	<1 s (NurM66)	☢	α (NurM66)	F	excit (NurM66)	α	6.69	O^{16} on Pt, N^{14} on Au, C^{12} on Hg (NurM66)
Rn^{202}	13 s (NurM66)	☢	α (NurM66)	D	cross bomb, excit (NurM66)	α	6.64	Au^{197}(N^{14}, 9n), O^{16} on Pt, C^{12} on Hg (NurM66)
Rn^{203}	45 s (NurM66)	☢	α (NurM66)	D	cross bomb, excit (NurM66)	α	6.50	Au^{197}(N^{14}, 8n), O^{16} on Pt, C^{12} on Hg (NurM66)
Rn^{203m}	28 s (NurM66)	☢	α (NurM66)	D	cross bomb, excit (NurM66)	α	6.55	Au^{197}(N^{14}, 8n), O^{16} on Pt, C^{12} on Hg (NurM66)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{86}\mathrm{Rn}^{204}$	75 s (NurM66)	☢ α (NurM66) Δ −7 (MTW)	B cross bomb, excit (NurM66)	α 6.42 [daughter radiations from Po^{200}]	$\mathrm{Au}^{197}(\mathrm{N}^{14}, 7n)$, O^{16} on Pt, C^{12} on Hg (NurM66)
Rn^{205}	1.8 m (NurM66)	☢ α (NurM66) Δ −7 (MTW)	B cross bomb, excit (NurM66) 6.29 α ($t_{1/2}$ 3 m) formerly assigned to Rn^{204} (StonA57, MomF55)	α 6.26	$\mathrm{Au}^{197}(\mathrm{N}^{14}, 6n)$, O^{16} on Pt, C^{12} on Hg (NurM66)
Rn^{206}	6.5 m (BurcW54, (NurM66) others (StonA57, BarabS57, WinnM54a)	☢ α 65%, EC 35% (StonA57, MomF55a) α 22%, EC 78% (BarabS57) Δ −9 (MTW)	B chem, genet (BurcW54, StonA57) parent Po^{202} (StonA57, MomF55a) 6.29 α ($t_{1/2}$ 3 m) formerly assigned to Rn^{204}	α 6.26 daughter radiations from At^{206}, Po^{202}, etc.	$\mathrm{Au}^{197}(\mathrm{N}^{14}, 5n)$ (BurcW54, StonA57, NurM66) C^{16} on Hg, O^{16} on Pt (NurM66)
Rn^{207}	11 m (BurcW54) 10 m (StonA57)	☢ EC 96%, α 4% (StonA57, MomF55a) Δ −9 (MTW)	A chem, genet (BurcW54) parent At^{207} (BurcW54, StonA57)	α 6.15 daughter radiations from At^{207}, Po^{203}, etc.	$\mathrm{Au}^{197}(\mathrm{N}^{14}, 4n)$ (StonA57, BurcW54)
Rn^{208}	23 m (MomF55a) 21 m (StonA57)	☢ EC ≈80%, α ≈20% (MomF55a, StonA57) Δ −10 (MTW)	B chem, genet (MomF55a) parent Po^{204} (MomF55a)	α 6.15 daughter radiations from At^{208}, Po^{204}, Bi^{204}	$\mathrm{Au}^{197}(\mathrm{N}^{14}, 3n)$ (StonA57) protons on Th^{232} (MomF55a)
Rn^{209}	30 m (MomF55a)	☢ EC 83%, α 17% (MomF55a) Δ −9 (MTW)	B chem, genet (MomF55a) daughter Ra^{213}, parent At^{209} (MomF55a, MomF52)	α 6.04 daughter radiations from Po^{205}, At^{209}	daughter Ra^{213}, from protons on Th^{232} (MomF55a)
Rn^{210}	2.42 h (CrofP64) 2.7 h (MomF52, MomF55a) 2.1 h (GhiA49)	☢ α ≈96%, EC ≈4% (MomF55a) Δ −9.74 (MTW)	A chem, genet (MomF55a, MomF52) parent Po^{206} (MomF52, MomF55a)	α 6.04 daughter radiations from At^{210}, Po^{206}	protons on Th^{232} (MomF52, MomF55a)
Rn^{211}	15 h (CrofP64) 16 h (MomF52, MomF55a)	☢ EC 74%, α 26% Δ −8.75 (MTW)	A chem, genet (MomF52) mass spect (AstG63) parent At^{211} (MomF52, MomF55a) parent Po^{207} (StonA56)	α 5.85 (9%), 5.78 (17%) γ At X-rays, 0.445 (29%), 0.680 (74%), 0.865 (18%), 0.946 (21%), 1.13 (23%), 1.37 (38%) e^- 0.053, 0.065, 0.073, 0.153, 0.168, 0.200, 0.237, 0.349, 0.584, 0.665 daughter radiations from At^{211}, Po^{211}	protons on Th^{232} (MomF55, MomF55a)
Rn^{212}	25 m (CrofP64) 23 m (GhiA49, HydE50, MomF52)	☢ α (HydE50) Δ −8.66 (MTW)	A chem, genet (HydE50, GhiA49) daughter Fr^{212}, parent Po^{208} (HydE50, MomF52)	α 6.27	daughter Fr^{212} (HydE50)
Rn^{215}	≈10^{-6} s est (MeiW52)	☢ α (MeiW52) Δ −1.2 (MTW)	B genet (MeiW52) daughter Ra^{219}, parent Po^{211} (AcC') (MeiW52)	α 8.6 daughter radiations from Po^{211}	descendant U^{227} (HydE64)
Rn^{216}	4.5×10^{-5} s delay coinc (RuiC61)	☢ α (MeiW49, MeiW51) β stable (cons energy) (ForB58) Δ 0.25 (MTW)	A genet (MeiW49, MeiW51) daughter Ra^{220}, parent Po^{212} (ThC') (MeiW49, MeiW51)	α 8.05 daughter radiations from Po^{212}	descendant U^{228} (HydE64)
Rn^{217}	5.4×10^{-4} s delay coinc (RuiC61) others (MeiW51)	☢ α (MeiW51) β stable (cons energy) (ForB58) Δ 3.65 (MTW)	A genet (MeiW49, MeiW51) daughter Ra^{221}, parent Po^{213} (MeiW49, MeiW51)	α 7.74 daughter radiations from Po^{213}	descendant U^{229} (MeiW49, MeiW51, HydE64)
Rn^{218}	0.035 s delay coinc (DiaH63) others (RuiC61, StuM48)	☢ α (StuM48) β stable (cons energy) (ForB58) Δ 5.22 (MTW)	A genet (StuM48) daughter Ra^{222}, parent Po^{214} (RaC') (StuM48)	α 7.14 (99.8%) γ 0.609 (0.2%) daughter radiations from Po^{214}	descendant U^{230} (HydE64)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12} \equiv 0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations approximate energies (MeV) and intensities	Principal means of production
$_{86}\mathrm{Rn}^{219}$ (An)	4.00 s (RodenH61) 3.92 s (CuriM31)	☢ α; β^- unstable (cons energy) (MTW) Δ 8.85 (MTW)	A chem, genet (CuriM31) daughter Ra^{223} (AcX), parent Po^{215} (AcA) daughter At^{219} (HydE53)	α 6.82 (81%), 6.55 (11%), 6.42 (8%) γ Po X-rays, 0.272 (9%), 0.401 (5%) e^- 0.179, 0.255, 0.308 daughter radiations from Po^{215}, etc.	descendant Th^{227} (HydE64)
Rn^{220} (Tn)	55.3 s (GinJ63) 56.3 s (RodenH61) 54.5 s (CuriM31) 51.5 s (SchmH55)	☢ α; β stable (cons energy) (ForB58) Δ 10.61 (MTW) σ_c <0.2 (GoldmDT64)	A chem, genet (CuriM31) daughter Ra^{224} (ThX), parent Po^{216} (ThA)	α 6.29 (100%) γ 0.55 (0.07%) daughter radiations from Po^{216}	natural source, descendant Th^{228} (HydE64)
Rn^{221}	25 m (MomF56)	☢ β^- ≈80%, α ≈20% (MomF56) Δ 14 (MTW)	B chem, genet (MomF56, MomF52) parent Fr^{221}, parent Po^{217} (MomF56, MomF52)	α 6.0 daughter radiations from Fr^{221}, Po^{217}, etc.	protons on Th^{232} (MomF52)
Rn^{222} (Rn)	3.8229 d (MarinP56) 3.825 d (TobJ55, TobJ51, RobeJ56a, CuriM31)	☢ α; β stable (cons energy) (ForB58) no β^-, lim 1×10^{-4}% (KarlB46) Δ 16.39 (MTW) σ_c 0.7 (GoldmDT64)	A chem, genet (CuriM31) daughter Ra^{226}, parent Po^{218} (RaA)	α 5.49 (100%) γ 0.510 (0.07%) daughter radiations from Po^{218}, etc.	natural source (HydE64)
Rn^{223}	43 m (ButeF64)	☢ [β^-] (BellA61)	B genet, chem (BellA61, ButeF64) ancestor Ra^{223} (AcX) (BellA61, ButeF64)	daughter radiations from Fr^{223}	protons on Th^{232} (BellA61, ButeF64)
Rn^{224}	1.9 h (ButeF64)	☢ [β^-] (BellA61)	B genet, chem (BellA61, ButeF64) ancestor Ra^{224} (ThX) (BellA61, ButeF64)		protons on Th^{232} (BellA61)
$_{87}\mathrm{Fr}^{204}$	2.0 s (GrifR64)	☢ α (GrifR64)	C excit, decay charac (GrifR64)	α 7.03	$\mathrm{Au}^{197}(\mathrm{O}^{16}, 9n)$ (GrifR64)
Fr^{205}	3.7 s (GrifR64)	☢ α (GrifR64)	B excit, genet (GrifR64) parent At^{201} (GrifR64)	α 6.92 daughter radiations from At^{201}	$\mathrm{Au}^{197}(\mathrm{O}^{16}, 8n)$ (GrifR64)
Fr^{206}	15.8 s (GrifR64)	☢ α (GrifR64) Δ ~0 (MTW)	B excit, cross bomb (GrifR64)	α 6.80	$\mathrm{Au}^{197}(\mathrm{O}^{16}, 7n)$, $\mathrm{Tl}^{203}(\mathrm{C}^{12}, 9n)$ (GrifR64)
Fr^{207}	19 s (GrifR64)	☢ α (GrifR64) Δ −2 (MTW)	B excit, cross bomb (GrifR64)	α 6.78	$\mathrm{Au}^{197}(\mathrm{O}^{16}, 6n)$, $\mathrm{Tl}^{203}(\mathrm{C}^{12}, 8n)$ (GrifR64)
Fr^{208}	37 s (GrifR64)	☢ α (GrifR64) Δ −2 (MTW)	B excit, cross bomb (GrifR64)	α 6.66	$\mathrm{Au}^{197}(\mathrm{O}^{16}, 5n)$, $\mathrm{Tl}^{203}(\mathrm{C}^{12}, 7n)$ (GrifR64)
Fr^{209}	55 s (GrifR64)	☢ α (GrifR64) Δ −3 (MTW)	B genet, excit, cross bomb (GrifR64) parent At^{205} (GrifR64)	α 6.66	$\mathrm{Au}^{197}(\mathrm{O}^{16}, 4n)$, $\mathrm{Tl}^{203}(\mathrm{C}^{12}, 6n)$ (GrifR64)
Fr^{210}	2.6 m (GrifR64)	☢ α (GrifR64) Δ −3 (MTW)	B excit, cross bomb (GrifR64)	α 6.56	$\mathrm{Tl}^{203}(\mathrm{C}^{12}, 5n)$, $\mathrm{Tl}^{205}(\mathrm{C}^{12}, 7n)$, $\mathrm{Au}^{197}(\mathrm{O}^{16}, 3n)$ (GrifR64)
Fr^{211}	3.1 m (GrifR64)	☢ α (GrifR64) EC unstable (cons energy) (MTW) Δ −4.3 (MTW)	B chem, genet, excit (GrifR64) parent At^{207} (GrifR64)	α 6.56 daughter radiations from At^{207}	$\mathrm{Tl}^{203}(\mathrm{C}^{12}, 4n)$, $\mathrm{Tl}^{205}(\mathrm{C}^{12}, 6n)$ (GrifR64)
Fr^{212}	19.3 m (HydE50)	☢ EC 56%, α 44% (HydE50) Δ −4 (MTW)	A chem, genet (HydE50) chem, mass spect (MomF52) parent Rn^{212}, parent At^{208} (HydE50, MomF52)	α 6.42 (16%), 6.39 (17%), 6.35 (11%) daughter radiations from Rn^{212}, At^{208}	protons on Th^{232} (HydE50)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns		Class; Identification; Genetic relationships		Major radiations: approximate energies (MeV) and intensities		Principal means of production
$_{87}Fr^{213}$	34 s (GrifR64)	☢ Δ	α 99+%, EC 0.5% (GrifR64) -3.55 (MTW)	A	chem, genet, excit, cross bomb (GrifR64) parent At^{209} (GrifR64)	α	6.78	$Tl^{205}(C^{12}, 4n)$, $Pb^{208}(B^{11}, 6n)$ (GrifR64)
Fr^{217}	[short] (KeyJ51)	☢ Δ	α (KeyJ51) EC unstable (cons energy) (MTW) 4.4 (MTW)	E	genet, decay charac (KeyJ51) descendant Pa^{225} (KeyJ51)	α	8.3	descendant Pa^{225} (KeyJ51)
Fr^{218}	5×10^{-3} s est (MeiW51)	☢ Δ	α (MeiW51) EC unstable (cons energy) (MTW) 7.00 (MTW)	B	genet (MeiW49, MeiW51) daughter Ac^{222}, parent At^{214} (MeiW49, MeiW51)	α	7.85 (93%) daughter radiations from At^{214}	descendant Pa^{226} (MeiW49, MeiW51)
Fr^{219}	0.02 s delay coinc (MeiW51)	☢ Δ	α (GhiA48) β stable (cons energy) (ForB58) 8.61 (MTW)	A	genet (GhiA48) daughter Ac^{223}, parent At^{215} (GhiA48, MeiW49, MeiW51)	α	7.31 daughter radiations from At^{215}	descendant Pa^{227} (HydE64)
Fr^{220}	27.5 s (MeiW51)	☢ Δ	α (GhiA48) β^-, EC unstable (cons energy) (MTW) 11.47 (MTW)	A	genet (GhiA48) daughter Ac^{224}, parent At^{216} (GhiA48, MeiW49, MeiW51)	α	6.68 (85%), 6.64 (13%) daughter radiations from At^{216}, etc.	descendant Pa^{228} (HydE64)
Fr^{221}	4.8 m (HageF50) others (EnglA47)	☢ Δ	α (EnglA47, HageF47) no β^-, lim 0.1% (ValliK64) β^- unstable (cons energy) (MTW) 13.27 (MTW)	A	chem, genet (HageF47, EnglA47) daughter Ac^{225}, parent At^{217} (EnglA47, HageF47, CranT48, HageF50) daughter Rn^{221} (MomF56, MomF52)	α γ e^-	6.34 (82%), 6.12 (15%) At X-rays, 0.218 (14%) 0.122, 0.202 daughter radiations from At^{217}, etc.	ancestor Th^{229} (EnglA47, HageF47, HageF50)
Fr^{222}	14.8 m (HydE50a)	☢ Δ	β^- 99+%, α 0.01-0.1% (HydE51a) 16.34 (MTW)	B	chem, genet (HydE50a) parent Ra^{222}, ancestor Bi^{214} (RaC) (HydE50a, HydE51a)		daughter radiations from Ra^{222}, etc.	protons on Th^{232} (HydE50a)
Fr^{223} (AcK)	22 m genet (PereyM56, AdlJ55, PereyM39)	☢ Δ	β^- (PereyM39a, GuiM47) α ≈4 x 10^{-3}% (HydE53) α ≈6 x 10^{-3}% (AdlJ55, PereyM56) 18.40 (MTW)	A	chem, genet (PereyM39, PereyM39b) daughter Ac^{227}, parent Ra^{223} (AcX) (PereyM39, PereyM39a, PereyM39b, PereyM41, PereyM46, GuiM47, LecM50) parent At^{219} (HydE53)	β^- e^- γ	1.15 max 0.031, 0.045, 0.062, 0.075 Ra L X-rays, 0.050 (40%), 0.080 (13%), 0.234 (4%)	natural source (HydE64)
Fr^{224}	<2m (ButeF64)	☢ Δ	[β^-] (BellA61) 22 (MTW)	F	genet (BellA61) daughter Rn^{224}, parent Ra^{224} (ThX) (BellA61)			daughter Rn^{224} (BellA61)
$_{88}Ra^{213}$	2.7 m (MomF55a)	☢ Δ	α (MomF52) -0 (MTW)	B	chem, genet (MomF52) parent Rn^{209} (MomF52, MomF55a)	α	6.91	$Pb^{206}(C^{12}, 5n)$, protons on Th^{232} (MomF52, MomF55)
Ra^{219}	≈10^{-3} s est (MeiW52)	☢ Δ	α (MeiW52) 9.4 (MTW)	B	genet (MeiW52) daughter Th^{223}, parent Rn^{215} (MeiW52)	α	8.0 daughter radiations from Rn^{215}, Po^{211}	descendant U^{227} (HydE64)
Ra^{220}	0.023 s (RuiC61)	☢ Δ	α (MeiW51) 10.27 (MTW)	A	genet (MeiW49, MeiW51) daughter Th^{224}, parent Rn^{216} (MeiW49, MeiW51)	α γ	7.46 (99%) 0.465 (1%) daughter radiations from Rn^{216}, Po^{212}	descendant U^{228} (HydE64)
Ra^{221}	30 s (MeiW51) 28 s (TovP58)	☢ Δ	α (MeiW51) β stable (cons energy) (ForB58) 12.96 (MTW)	A	chem, genet (MeiW49, MeiW51) daughter Th^{225}, parent Rn^{217} (MeiW49, MeiW51)	α γ	6.76 (30%), 6.67 (20%), 6.61 (34%), 6.59 (8%) Rn X-rays, 0.091 (3.5%), 0.151 (13%), 0.175 (2%) daughter radiations from Rn^{217}, etc.	descendant U^{229} (MeiW49, MeiW51, RuiC61)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns		Class; Identification; Genetic relationships		Major radiations: approximate energies (MeV) and intensities		Principal means of production
$_{88}\mathrm{Ra}^{222}$	38 s (StuM48) 37 s (AsaF56)	☢ Δ	α (StuM48) β stable (cons energy) (ForB58) 14.32 (MTW)	A	chem, genet (StuM48) daughter Th^{226}, parent Rn^{218} (StuM48) daughter Fr^{222} (HydE50a, HydE51a)	α γ	6.56 (96%) 0.325 (4%), 0.473 (0.007%), 0.52 (0.004%), 0.85 (0.003%) daughter radiations from Rn^{218}, etc.	descendant U^{230} (StuM48)
Ra^{223} (AcX)	11.435 d (KirH65) 11.2 d (CuriM31) 11.7 d (HageG54) others (BaeA53, SeaG47a)	☢ Δ σ_c	α; β stable (cons energy) (ForB58) 17.26 (MTW) 130 (GoldmDT64)	A	chem, genet (CuriM31) daughter Th^{227} (RdAc), parent Rn^{219} (An); daughter Ac^{223} (MeiW51) daughter Fr^{223} (AcK) (PereyM39, PereyM39a, PereyM39b, PereyM41, PereyM46, GuiM47, LecM50) descendant Rn^{223} (BellA61, ButeF64)	α γ e$^-$	5.75 (9%), 5.71 (54%), 5.61 (26%), 5.54 (9%) Rn X-rays, 0.149 (10%, complex), 0.270 (10%), 0.33 (6%, complex) 0.024, 0.046, 0.056, 0.126, 0.136, 0.171 daughter radiations from Rn^{219}, Po^{215}, Pb^{211}, etc.	daughter Th^{227} (HydE64)
Ra^{224} (ThX)	3.64 d (CuriM31) others (SeaG47a)	☢ Δ σ_c	α; β stable (cons energy) (ForB58) 18.82 (MTW) 12 (GoldmDT64)	A	chem, genet (CuriM31) daughter Th^{228} (RdTh), parent Rn^{220} (Tn); daughter Ac^{224} (GhiA48, MeiW49, MeiW51) descendant Rn^{224} (BellA61, ButeF64)	α γ e$^-$	5.68 (94%), 5.45 (6%) Rn X-rays, 0.241 (3.7%), 0.29 (0.008%), 0.41 (0.004%), 0.65 (0.009%) 0.144, 0.225 daughter radiations from Rn^{220}, Po^{216}, Pb^{212}, etc.	daughter Th^{228}, from natural source (HydE64)
Ra^{225}	14.8 d (HageF50) others (EnglA47)	☢ Δ	β$^-$ (EnglA47, HageF47) no α, lim 10^{-4}% (MalkL60) others (MomF56) 22.01 (MTW)	A	chem, genet (EnglA47, HageF47) daughter Th^{229}, parent Ac^{225} (EnglA47, HageF47, HageF50)	β$^-$ e$^-$ γ	0.36 max 0.021, 0.035 Ac L X-rays, 0.040 (33%) daughter radiations from Ac^{225}, etc.	descendant U^{233}, Th^{229} (HydE64)
Ra^{226}	1602 y sp act (MartiG59) 1622 y sp act (KohT49) 1617 y sp act (SebW56) 1590 y sp act (CuriM31) others (GorsG58, GorsG59)	☢ Δ σ_c	α; β stable (cons energy) (ForB58) 23.69 (MTW) 20 (GoldmDT64)	A	chem, genet (CuriM31) daughter Th^{230} (Io), parent Rn^{222} (Rn)	α γ e$^-$	4.78 (95%), 4.60 (6%) Rn X-rays, 0.186 (4%), 0.26 (0.007%), 0.42 (2 x 10^{-4}%), 0.61 (2 x 10^{-4}%) 0.087, 0.170 daughter radiations from Rn^{222}, Po^{218}, Pb^{214}, Bi^{214}, Po^{214}	natural source (HydE64)
Ra^{227}	41.2 m (ButlJP53)	☢ Δ	β$^-$ (PeteS49) 27.18 (MTW)	A	n-capt, genet (PeteS49) parent Ac^{227} (PeteS49)	β$^-$ e$^-$ γ	1.31 max 0.008, 0.023 [Ac X-rays], 0.291 (4%), 0.498 (0.6%)	Ra^{226} (n, γ) (PeteS49)
Ra^{228} (MsTh$_1$)	6.7 y (CuriM31)	☢ Δ σ_c	β$^-$; no α, lim 2 x 10^{-6}% (FeaN57) 28.96 (MTW) ≈36 (GoldmDT64)	A	chem, genet (CuriM31) daughter Th^{232}, parent Ac^{228} (MsTh$_2$)	β$^-$ e$^-$	0.05 max 0.005 daughter radiations from Ac^{228}, Th^{228}, Ra^{224}, etc.	natural source (HydE64)
Ra^{229}	[short] (DepF52)	☢	[β$^-$] (DepF52)	F	n-capt, genet (DepF52) [parent Ac^{229}] (DepF52)			Ra^{228}(n, γ) (DepF52)
Ra^{230}	1 h (JenkW52)	☢ Δ	β$^-$ (JenkW52) 35 (LHP, MTW)	D	chem (JenkW52) parent Ac^{230} (JenkW52)	β$^-$	1.2 max	[Th^{232}(d, 3pn)] (JenkW52)
$_{89}\mathrm{Ac}^{221}$	[short] (KeyJ51)	☢ Δ	α (KeyJ51) EC unstable (cons energy) (MTW) 14.6 (MTW)	E	genet, decay charac (KeyJ51) descendant Pa^{225} (KeyJ51)	α	7.6	ancestor Pa^{225} (KeyJ51)
Ac^{222}	5.5 s (MeiW52) 4.2 s (TovP58)	☢ Δ	α (MeiW51) EC unstable (cons energy) (MTW) 16.55 (MTW)	B	genet (MeiW49, MeiW51) daughter Pa^{226}, parent Fr^{218} (MeiW49, MeiW51, MeiW52)	α	7.00 (93%) daughter radiations from Fr^{218}, etc.	daughter Pa^{226} (MeiW49, MeiW51, MeiW52) Ra^{226}(p, 5n) (TovP58)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{89}Ac^{223}$	2.2 m (MeiW51)	☢ α 99%, EC 1% (MeiW51) Δ 17.82 (MTW)	A genet (GhiA48) daughter Pa^{227}, parent Fr^{219}, parent Ra^{223} (AcX) (GhiA48, MeiW49, MeiW51)	α 6.66 (38%), 6.65 (42%), 6.57 (13%) γ Fr L X-rays, 0.082 (0.2%), 0.096 (0.2%) daughter radiations from Fr^{219}, etc.	daughter Pa^{227} (MeiW51)
Ac^{224}	2.9 h (MeiW51)	☢ EC ≈90%, α ≈10% (MeiW51) β^- unstable (cons energy) (MTW) Δ 20.21 (MTW)	A chem, genet (GhiA48) daughter Pa^{228}, parent Fr^{220}, parent Ra^{224} (GhiA48, MeiW49, MeiW51)	γ Ra X-rays, 0.132 (28%), 0.217 (62%) e^- 0.067, 0.080 α 6.20 (3%), 6.14 (3%), 6.04 (3%) daughter radiations from Fr^{220}, etc.	daughter Pa^{228} (MeiW51)
Ac^{225}	10.0 d (HageF50, EnglA47)	☢ α (EnglA47, HageF47) β stable (cons energy) (ForB58) Δ 21.62 (MTW)	A chem, genet (HageF47, EnglA47) daughter Ra^{225}, parent Fr^{221} (HageF47, EnglA47, HageF50, CranT48) daughter Pa^{229} (HydE49a) daughter Th^{225} (MeiW49, MeiW51)	α 5.83 (54%), 5.79 (28%), 5.73 (10%, doublet) γ Fr X-rays, 0.099, 0.150, 0.187 e^- 0.020, 0.032, 0.044, 0.081 daughter radiations from Fr^{221}, At^{217}, etc.	descendant U^{233}, Th^{229} Ra^{226}(d, 3n) (HydE64)
Ac^{226}	29 h (StreK50)	☢ β^- ≈80%, EC ≈20% (StepF57d) α ? (weak) (MCoyJ64) Δ 24.31 (MTW)	A chem, genet (StreK48) daughter Pa^{230}, parent Th^{226} (StreK48, StreK50, MeiW50)	β^- 1.2 max e^- 0.053, 0.067 γ Th L X-rays, Ra X-rays, 0.158 (32%), 0.185 (9%), 0.230 (47%), 0.253 (11%) α 5.44 ? daughter radiations from Th^{226}, etc.	Ra^{226}(d, 2n) (HydE64)
Ac^{227}	21.6 y (TobJ55) 22.0 y (HollaJ50) 21.7 y (CuriI44) 21.2 y (ShimN56b) others (CuriM31)	☢ β^- 99% (PereyM39, PeteS49a) α 1.4% (NurM65a) α 1.2% (MeyS14, PereyM39, PereyM46, PeteS49a) Δ 25.87 (MTW) σ_c 830 (GoldmDT64)	A chem, genet (CuriM31) daughter Pa^{231}, parent Th^{227} (RdAc); parent Fr^{223} (PereyM39, PereyM46, GuiM47, LecM50) daughter Ra^{227} (PeteS49)	β^- 0.046 max e^- 0.005, 0.010 γ Th L X-rays, 0.070 [0.08%], 0.166, 0.190 α 4.95 (1.2%, doublet), 4.86 (0.18%, doublet) daughter radiations from Th^{227}, Ra, ^{223}, Fr^{223}, etc.	Ra^{226}(n, γ)Ra^{227}(β^-) (PeteS49) natural source (HydE64)
Ac^{228} ($MsTh_2$)	6.13 h (CuriM31)	☢ β^-; Δ 28.91 (MTW)	A chem, genet (CuriM31) daughter Ra^{228} ($MsTh_1$), parent Th^{228} (RdTh)	β^- 2.11 max e^- 0.040, 0.054, 0.110 γ Th X-rays, 0.34 (15%, complex), 0.908 (25%), 0.96 (20%, complex)	natural source (HydE64)
Ac^{229}	66 m (DepF52)	☢ β^- (DepF52) Δ 31 (MTW)	B chem, n-capt (DepF52) daughter Ra^{229} (DepF52)		Ra^{228}(n, γ)[Ra^{229}]β^- (DepF52)
Ac^{230}	<1 m genet (JenkW52)	☢ β^- (JenkW52) Δ 34 (MTW)	F genet (JenkW52) daughter Ra^{230} (JenkW52)	β^- 2.2 max	daughter Ra^{230} (JenkW52)
Ac^{231}	15 m (TakaK60a)	☢ β^- (TakaK60a) Δ 35.9 (MTW)	C excit (TakaK60a)	β^- 2.1 max γ 0.185, 0.28, 0.39, 0.71	Th^{232}(γ, p) (TakaK60a)
$_{90}Th^{223}$	0.9 s (TovP58) ≈0.1 s est (MeiW52)	☢ α (MeiW52) EC unstable (cons energy) (MTW) Δ 19.5 (MTW)	B genet (MeiW52) daughter U^{227}, parent Ra^{219} (MeiW52)	α 7.56 [daughter radiations from Ra^{219}, etc.]	daughter U^{227} (MeiW52)
Th^{224}	1.05 s (TovP58)	☢ α (MeiW51) β stable (cons energy) (ForB58) Δ 20.00 (MTW)	A genet (MeiW49, MeiW51) daughter U^{228}, parent Ra^{220} (MeiW49, MeiW51)	α 7.18 (79%), 6.91 (19%) γ Ra X-rays, 0.177 (9%), 0.235 (0.4%), 0.297 (0.3%), 0.410 (0.8%) daughter radiations from Ra^{220}, etc.	daughter U^{228} (MeiW51, RuiC61)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}≡0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{90}\mathrm{Th}^{225}$	8.0 m (MeiW51)	☢ α ≈90%, EC ≈10% (MeiW51) Δ 22.30 (MTW)	A chem, genet (MeiW49, MeiW51) daughter U^{229}, parent Ra^{221}, parent Ac^{225} (MeiW49, MeiW51)	α 6.80 (8%), 6.75 (6%), 6.50 (12%), 6.48 (39%), 6.44 (13%) γ [Ac X-rays], Ra X-rays, 0.246 (5%), 0.322 (27%), 0.362 (5%), 0.45 (1%), 0.49 (1%) daughter radiations from Ra^{221}, etc.	daughter U^{229} (MeiW49, MeiW51)
Th^{226}	30.9 m (StuM48)	☢ α (StuM48) β stable (cons energy) (ForB58) Δ 23.19 (MTW)	A chem, genet (StuM48) daughter U^{230}, parent Ra^{222} (StuM48) daughter Ac^{226} (StreK48, StreK50)	α 6.34 (79%), 6.22 (19%) γ Ra X-rays, 0.111 (3.4%), 0.131 (0.34%), 0.20 (0.4%, complex), 0.242 (1.2%) e$^-$ 0.094, 0.107 daughter radiations from Ra^{222}, Rn^{218}, etc.	daughter U^{230} (HydE64)
Th^{227} (RdAc)	18.2 d (HageG54) others (PeteS49b, CuriM31)	☢ α; β stable (cons energy) (ForB58) Δ 25.82 (MTW) σ$_f$ ≈1500 (GoldmDT64)	A chem, genet (CuriM31) daughter Ac^{227}, parent Ra^{223} (AcX) daughter Pa^{227} (MeiW51, GhiA48) daughter U^{231} (CranW50)	α 6.04 (23%), 5.98 (24%), 5.76 (21%), 5.72 (14%, doublet) γ Ra X-rays, 0.050 (8%), 0.237 (15%, complex), 0.31 (8%, complex) e$^-$ 0.013, 0.026, 0.044, others daughter radiations from Ra^{223}, Rn^{219}, Po^{215}, etc.	daughter Ac^{227}, from natural source or from Ra^{226}(n, γ)Ra^{227}(β$^-$) (HydE64)
Th^{228} (RdTh)	1.910 y (KirH56) others (CuriM31)	☢ α; β stable (cons energy) (ForB58) Δ 26.77 (MTW) σ$_c$ 123 (GoldmDT64) σ$_f$ <0.3 (GoldmDT64)	A chem, genet (CuriM31) daughter Ac^{228} (MsTh$_2$); parent Ra^{224} (ThX); daughter U^{232} (GofJ49) daughter Pa^{228} (MeiW51)	α 5.43 (71%), 5.34 (28%) γ Ra L X-rays, 0.084 (1.6%), 0.132 (0.2%), 0.167 (0.1%), 0.214 (0.3%) e$^-$ 0.067, 0.080 daughter radiations from Ra^{224}, Rn^{220}, Po^{216}, etc.	natural source daughter U^{232} Ra^{226}(n, γ)Ra^{227}(β$^-$) Ac^{227}(n, γ)Ac^{228}(β$^-$) (HydE64)
Th^{229}	7340 y genet (HageF50) others (EnglA47)	☢ α; β stable (cons energy) (ForB58) Δ 29.61 (MTW) σ$_f$ 32 (GoldmDT64)	A chem, genet (EnglA47, HageF47, HageF50) daughter U^{233}, parent Ra^{225} (EnglA47, HageF47, HageF50)	α 5.05 (7%), 4.97 (complex, 10%), 4.90 (11%), 4.84 (58%), 4.81 (11%) γ Ra X-rays, 0.137 (≈3%, complex), 0.20 (≈10%, doublet) e$^-$ 0.006–0.090 daughter radiations from Ra^{225}, Ac^{225}, etc.	daughter U^{233} (HydE64)
Th^{230} (Io)	8.0 x 10^4 y sp act (HydE49) 7.5 x 10^4 y sp act (AttR62) 8.2 x 10^4 y genet (CuriM30) t$_{1/2}$ (SF) ≥1.5 x 10^{17} y (SegE52)	☢ α; β stable (cons energy) (ForB58) Δ 30.87 (MTW) σ$_c$ 23 (GoldmDT64) σ$_f$ ≤0.001 (GoldmDT64)	A chem, genet (CuriM31) daughter U^{234} (U$_{II}$), parent Ra^{226}; daughter Pa^{230} (StuM48a)	α 4.68 (76%), 4.62 (24%) γ Ra L X-rays, 0.068 (0.6%), 0.142 (0.07%), 0.184 (0.014%), 0.253 (0.017%) e$^-$ 0.051, 0.064 daughter radiations from Ra^{226}, Rn^{222}, etc.	natural source (HydE64)
Th^{231} (UY)	25.52 h (CabM58) 25.6 h (JafAH51) 25.5 h (KniG49) others (CuriM31, GratO32, NisY38)	☢ β$^-$; Δ 33.83 (MTW)	A chem, genet (CuriM31) daughter U^{235} (AcU), parent Pa^{231}	β$^-$ 0.30 max e$^-$ 0.040, 0.054, 0.061 γ Pa L X-ray , 0.026 (2%), 0.084 (10%, complex)	Th^{230}(n, γ) (BaranS60, HoltzM66) daughter U^{235}
Th^{232}	1.41 x 10^{10} y sp act, (FarlT60) others (KovAF38, PicE56, MackR56, SenF56) t$_{1/2}$ (SF): >10^{21} y (FleG58) others (PocA55, SegE52)	☢ α; β stable (cons energy) (ForB58) % 100 (AstF35, DempA36) Δ 35.47 (MTW) σ$_c$ 7.4 (GoldmDT64) σ$_f$ <0.0002 (GoldmDT64)	A chem, genet (CuriM31) parent Ra^{228} (MsTh$_1$)	α 4.01 (76%), 3.95 (24%) γ [Ra L X-rays] e$^-$ 0.042, 0.055 daughter radiations from Ra^{228}, Ac^{228}, Th^{228}, Ra^{224}, etc.	natural source (HydE64)
Th^{233}	22.12 m (JenkE55) 22.4 m (DroB57) 22.3 m (BunkM50a) 22.5 m (SeaG47) others (RutW52, GrossA41)	☢ β$^-$ (SeaG47) Δ 38.76 (MTW) σ$_c$ 1500 (GoldmDT64) σ$_f$ 15 (GoldmDT64)	A chem, n-capt (MeiL38) parent Pa^{233} (MeiL38, GrossA41, SeaG41a, HahO41, SeaG47)	β$^-$ 1.23 max e$^-$ 0.009, 0.024, 0.036, 0.051, 0.067, 0.082 γ Pa X-rays, 0.029 (2.1%), 0.087 (2.7%), 0.171 (0.7%), 0.195 (0.3%), 0.453 (1%), 0.67 (0.25%), 0.895 (0.14%)	Th^{232} (n, γ) (MeiL38, SeaG47, SeaG41a, GrossA41)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{90}$Th^{234} (UX$_1$)	24.10 d (KniG48) others (SargB39a, CuriM31)	☢ β$^-$; no α, lim 10^{-4}% (DeuS55) Δ 40.64 (MTW) σ_c 1.8 (GoldmDT64) σ_f <0.01 (GoldmDT64)	A chem, genet (CuriM31) daughter U^{238}, parent Pa^{234m} (UX$_2$); ancestor Pa^{234} (UZ) (ZijW54)	β$^-$ 0.191 max e$^-$ 0.012, 0.025, 0.072, 0.088 γ Pa L X-rays, 0.063 (3.5%, doublet), 0.093 (4%, doublet) daughter radiations from Pa^{234m}	natural source (HydE64)
Th^{235}	<<10 m genet (HarvB50)	☢ [β$^-$] (HarvB50)	F n-capt, genet (HarvB50) [parent Pa^{235}] (HarvB50)		Th^{234}(n, γ) (HarvB50)
$_{91}$Pa^{224}	0.6 s (TovP58)	☢ α (TovP58)	F decay charac (TovP58)		Th^{232}(p, 9n) (TovP58)
Pa^{225}	0.8 s (TovP58) 2.0 s (KeyJ51)	☢ α (KeyJ51) Δ 25 (MTW)	E excit, decay charac (KeyJ51, TovP58) ancestor Ac^{221}, Fr^{217}, At^{213} (KeyJ51)		Th^{232} (p, 8n) (TovP58, KeyJ51)
Pa^{226}	1.8 m (MeiW51)	☢ α 74%, EC 26% (MCoyJ64) Δ 25.96 (MTW)	B chem, genet (MeiW49, MeiW51) parent Ac^{222} (MeiW49, MeiW51, MeiW52)	α 6.86 (38%), 6.82 (34%) daughter radiations from Ac^{222}, Th^{226}, etc.	Th^{232}(p, 7n) (MeiW49, MeiW51, MeiW52)
Pa^{227}	38.3 m (MeiW51) others (OConP48)	☢ α ≈85%, EC ≈15% (MeiW51) Δ 26.83 (MTW)	A chem, genet (GhiA48) parent Ac^{223}, parent Th^{227} (RdAc) (GhiA48, MeiW51) daughter Np^{231} (MagL50)	γ [Th X-rays], Ac L X-rays, 0.065 (6%, complex), 0.110 (2%) α 6.47 (43%), 6.42 (23%, complex), 6.40 (8%), 6.36 (7%) daughter radiations from Ac^{223}, etc.	Th^{232}(d, 7n) (MeiW56, SubV63) Th^{232}(p, 6n) (MeiW56, HillM58)
Pa^{228}	22 h (MeiW51)	☢ EC ≈98%, α ≈2% (MeiW51) Δ 28.86 (MTW)	A chem, genet (GhiA48) daughter U^{228}, parent Ac^{224}, parent Th^{228} (RdTh) (GhiA48, MeiW49, MeiW51)	γ Th X-rays, 0.14 (3%), 0.20 (9%), 0.28 (5%), 0.33 (18%), 0.41 (13%), 0.46 (32%), 0.95 (93%), 1.57 (7%), 1.85 (4%), all γ's complex e$^-$ 0.040, 0.054, 0.110 α 6.11 (1%, complex), 6.08 (0.4%), 6.03 (0.2%), 5.80 (0.2%), others daughter radiations from Ac^{224}, etc.	Th^{232}(p, 5n) (ArbE60) Th^{232}(d, 6n) (HydE64) Th^{230}(d, 4n) (HillM58)
Pa^{229}	1.5 d (HydE49b)	☢ EC 99+%, α 0.25% (SlaLM51) others (MeiW51) Δ 29.88 (MTW)	A chem, genet (HydE49a) parent Ac^{225} (HydE49a) daughter U^{229} (MeiW51, MeiW49)	γ Th X-rays e$^-$ 0.023, 0.038 α 5.67 (0.05%), 5.62 (0.07%, complex), 5.58 (0.10%), 5.54 (0.03%)	daughter U^{229} (MeiW51, SubV63) Th^{230}(d, 3n) (HydE49a) Th^{232}(p, 4n) (SubV63)
Pa^{230}	17.7 d (OsbD49) 17.0 d (StuM48) others (HydE49a, HydE49b)	☢ EC 89.6%, β$^-$ 10.4%, α 0.0032% (BastG65a) β$^+$? (≈0.03%) (OngP55a) others (BriaJ65a, MCoyJ64, MeiW51) Δ 32.17 (MTW) σ_f 1500 (GoldmDT64)	A chem, excit, genet (StuM48) parent U^{230} (StuM48, OsbD49) parent Th^{230} (Io) (StuM48a) parent Ac^{226} (MeiW50)	β$^-$ 0.41 max e$^-$ 0.034, 0.048 γ Th X-rays, 0.45 (18%, complex), 0.51 (6%, complex), 0.91 (24%, complex), 0.954 (50%) α 5.26–5.34 (complex) daughter radiations from U^{230}, Th^{226}, etc.	Th^{232}(p, 3n) (TewH55, MeiW56) Th^{232}(d, 4n) (MeiW56) Th^{230}(d, 2n) (HydE64)
Pa^{231}	3.25 x 10^4 y sp act (KirH61) 3.43 x 10^4 y sp act (v WinQ49) 3.2 x 10^4 y sp act (GrossA30)	☢ α; β stable (cons energy) (ForB58) Δ 33.44 (MTW) σ_c 200 (GoldmDT64) σ_f 0.010 (GoldmDT64)	A chem, genet (CuriM31) daughter Th^{231} (UY), parent Ac^{227}; daughter U^{231} (CranW50)	α 5.06 (10%), 5.02 (23%), 5.01 (24%), 4.95 (22%), 4.73 (11%) γ Ac X-rays, 0.027 (6%), 0.29 (6%, complex) e$^-$ 0–0.10, 0.195, 0.323, 0.350 daughter radiations from Ac^{227}, Th^{227}, Fr^{223}, Ra^{223}, etc.	natural source (HydE64)
Pa^{232}	1.31 d (BrowCI54) others (JafAH50, OsbD49, GofJ49, StuM48)	☢ β$^-$ (GofJ49) no EC, lim 2% (BrowCI52a) Δ 35.95 (MTW) EC unstable (cons energy) (MTW) σ_c ≈760 (GoldmDT64) σ_f ≈700 (GoldmDT64)	A chem, genet (GofJ49) parent U^{232} (GofJ49, OsbD49)	β$^-$ 1.3 max (0.7%), 0.32 max e$^-$ 0.028, 0.043, 0.091 γ U X-rays, 0.107 (5%, doublet), 0.150 (12%), 0.39 (9%, doublet), 0.46 (9%, doublet), 0.57 (8%, doublet), 0.87 (51%, complex), 0.971 (40%)	Pa^{231}(n, γ), Th^{232}(d, 2n) (HydE64) Th^{232}(p, n) (TewH55)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{91}Pa^{233}$	27.0 d (MIsaL56, WriH57) 27.4 d (GrossA41) others (StuM48, GofJ49)	☢ β^- (MeiL38, GrossA41, SeaG41a) Δ 37.51 (MTW) σ_c 21 (to Pa^{234}) 22 (to Pa^{234m}) (GoldmDT64) σ_f <0.1 (GoldmDT64)	A chem, genet (MeiL38, GrossA41, SeaG41a) daughter Th^{233} (MeiL38, GrossA41, SeaG41a, HahO41, SeaG47) parent U^{233} (SeaG47) daughter Np^{237} (HageF47, MagL47)	β^- 0.568 max (5%), 0.257 max e^- 0.013, 0.023, 0.036, 0.054, 0.065, 0.185, 0.197, 0.291 γ U X-rays, 0.31 (44%, complex)	$Th^{232}(n, \gamma)Th^{233}(\beta^-)$ (MeiL38, GrossA41, SeaG41a, HahO41, SeaG47) $Th^{232}(d, n)$ (StuM48, GofJ49)
Pa^{234} (UZ)	6.75 h (BjoS62) 6.66 h (ZijW54) 6.7 h (CuriM31)	☢ β^-; Δ 40.38 (MTW) σ_f <5000 (GoldmDT64)	A chem, genet (CuriM31) parent U^{234} (U_{II}); daughter Pa^{234m} (UX_2) (ZijW54)	β^- 1.3 max (≤2%), 1.13 max (13%), 0.53 max e^- 0.024, 0.039, 0.080, 0.095, 0.112 γ U X-rays, 0.100 (50%), 0.126 (26%), 0.22 (14%), 0.36 (13%), 0.56 (15%), 0.70 (24%), 0.90 (70%), 1.08 (12%), (many of the γ rays are complex)	natural source (HydE64)
Pa^{234m} (UX_2)	1.175 m (BareF51) 1.14 m (CuriM31)	☢ β^- 99+%, IT 0.13% (BjoS63a) others (FeaN38a, BradH45d, ZijW54) Δ 40.45 (LHP, MTW) σ_f <500 (GoldmDT64)	A chem, genet (CuriM31) daughter Th^{234} (UX_1), parent U^{234} (U_{II}); parent Pa^{234} (UZ) (ZijW54)	β^- 2.29 max γ U L X-rays, 0.765 (0.30%), 1.001 (0.60%)	natural source (HydE64)
Pa^{235}	23.7 m (MeiW50) others (HarvB50)	☢ β^- (MeiW50, HarvB50) Δ 42.3 (MTW)	B chem, excit, sep isotopes (MeiW50) genet (HarvB50) [daughter Th^{235}] (HarvB50)	β^- 1.4 max γ no γ	$Th^{234}(n, \gamma)[Th^{235}]\beta^-$ (HarvB50)
Pa^{236}	12 m (WolzG63) others (CranW54)	☢ β^- (WolzG63) Δ 45 (MTW)	D chem, decay charac (WolzG63)	β^- 3.3 max γ U L X-rays	$U^{238}(d, \alpha)$ (WolzG63)
Pa^{237}	39 m (TakaK60)	☢ β^- (TakaK60) Δ 47.7 (MTW)	B chem, excit (TakaK60)	β^- 2.3 max γ U X-rays, 0.090 (↑ 50), 0.145 (↑ 45), 0.205 (↑ 55), 0.275 (↑ 20), 0.330 (↑ 40), 0.405 (↑ 30), 0.46 (↑ 100), 0.55 (↑ 30), 0.59 (↑ 25), 0.75 (↑ 50), 0.80 (↑ 45), 0.87 (↑ 100), 0.92 (↑ 100), 1.04 (↑ 35), 1.32 (↑ 10), 1.42 (↑ 15)	$U^{238}(\gamma, p)$ (TakaK60)
$_{92}U^{227}$	1.3 m (MeiW52)	☢ α (MeiW52) Δ 29 (MTW)	B chem, genet (MeiW52) parent Th^{223} (MeiW52)	α 6.8 daughter radiations from Th^{223}, etc.	$Th^{232}(\alpha, 9n)$ (MeiW52)
U^{228}	9.1 m (RuiC61) others (MeiW51)	☢ α ≥95%, EC ≤5% (RuiC61) others (MeiW51) EC unstable (cons energy) (MTW) Δ 29.23 (MTW)	A chem, genet (MeiW49, MeiW51) parent Th^{224}, parent Pa^{228} (MeiW49, MeiW51) daughter Pu^{232} (JameR48, OrtD51a)	α 6.69 (↑ 70), 6.60 (↑ 29) γ Th X-rays, 0.152 (0.2%), 0.187 (0.3%), 0.246 (0.4%) daughter radiations from Th^{224}, etc.	$Th^{232}(\alpha, 8n)$ (RuiC61)
U^{229}	58 m (MeiW51)	☢ EC ≈80%, α ≈20% (MeiW51) Δ 31.20 (MTW)	A chem, genet (MeiW49, MeiW51) parent Th^{225}, parent Pa^{229} (MeiW49, MeiW51) daughter Pu^{233} (ThomT57)	γ Pa X-rays α 6.36 (13%), 6.33 (4%), 6.30 (3%) daughter radiations from Th^{225}, Pa^{229}, etc.	$Th^{232}(\alpha, 7n)$ (MeiW49, MeiW51)
U^{230}	20.8 d (StuM48)	☢ α (StuM48) β stable (cons energy) (ForB58) Δ 31.60 (MTW) σ_f 25 (GoldmDT64)	A chem, genet (StuM48) daughter Pa^{230} (StuM48, OsbD49) daughter Pu^{234} (PerlmI49, OrtD51a) parent Th^{226} (StuM48)	α 5.89 (67%), 5.82 (32%) γ Th L X-rays, 0.072 (0.54%), 0.156 (doublet, 0.034%), 0.231 (0.18%) e^- 0.054, 0.068 daughter radiations from Th^{226}, Ra^{222}, etc.	daughter Pa^{230} (HydE64)
U^{231}	4.3 d (CranW50) 4.2 d (OsbD49)	☢ EC 99+%, α 0.0055% (CranW50) Δ 33.8 (MTW) σ_f ≈400 (GoldmDT64)	A chem, sep isotopes, genet (OsbD49) genet (CranW50) parent Th^{227} (RdAc), parent Pa^{231} (CranW50)	γ Pa X-rays, 0.026, 0.084 (7%), 0.218 (1%) e^- 0.040, 0.054, 0.063 α 5.46	$Th^{230}(\alpha, 3n)$ (HollaJ56c) $Pa^{231}(d, 2n)$ (OsbD49) $Th^{232}(\alpha, 5n)$ (CranW50)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (△≡M−A), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{92}U^{232}$	72 y sp act, calorim (ChilJ64) others (SelP54, JameR49, GofJ49) $t_{1/2}$ (SF) ≈8 x 10^{13} y (HydE57)	☢ α (GofJ49) β stable (cons energy) (ForB58) Δ 34.60 (MTW) σ_c 78 (GoldmDT64) σ_f 77 (GoldmDT64)	A chem, genet (GofJ49) daughter Pa^{232} (GofJ49, OsbD49) daughter Pu^{236} (JameR49) parent Th^{228} (RdTh) (GofJ49)	α 5.32 (68%), 5.27 (32%) γ Th L X-rays, 0.058 (0.21%), 0.129 (0.082%), 0.270 (0.0038%), 0.328 (0.0034%) e^- 0.040, 0.054 daughter radiations from Th^{228}, Ra^{224}, Rn^{220}, etc.	daughter Pa^{232} (GofJ49) $Th^{232}(\alpha, 4n)$ (HydE64)
U^{233}	1.62 x 10^5 y sp act + mass spect (HydE52) 1.63 x 10^5 y sp act + mass spect (DokY59a, LineG45) 1.61 x 10^5 y sp act (PopD61) others (SeaG52)	☢ α (SeaG52) β stable (cons energy) (ForB58) Δ 36.94 (MTW) σ_c 49 (GoldmDT64) σ_f 524 (GoldmDT64)	A chem, genet (SeaG47, SeaG52) daughter Pa^{233} (SeaG47) parent Th^{229} (EngiA47, HageF47, HageF50)	α 4.82 (83%), 4.78 (15%) γ Th X-rays, 0.029 (↑ 60), 0.042 (↑ 310), 0.055 (↑ 68), 0.097 (↑ 100), 0.119 (↑ 40, complex), 0.146 (↑ 35, doublet), 0.164 (↑ 27), 0.22 (↑ 45, complex), 0.291 (↑ 23), 0.32 (↑ 43, doublet) e^- 0.023, 0.038 daughter radiations from Th^{229}, Ra^{225}, Ac^{225}, etc.	$Th^{232}(n, \gamma)Th^{233}(\beta^-)$ $Pa^{233}(\beta^-)$ (SeaG47)
U^{234} (U_{II})	2.47 x 10^5 y sp act (FleE52, WhiP65) others (KieC52, KieC49, GoldiA49, ChambO46) $t_{1/2}$ (SF) 2 x 10^{16} y (GhiA52)	☢ α; β stable (cons energy) (ForB58) % 0.0057 (LouM56) others (WhiF56) Δ 38.16 (MTW) σ_c 95 (GoldmDT64)	A chem, genet, mass spect (CuriM31) daughter Pa^{234m} (UX_2), daughter Pa^{234} (UZ), parent Th^{230} (Io)	α 4.77 (72%), 4.72 (28%) γ Th L X-rays, 0.053 (0.2%), 0.117, 0.48 (4 x 10^{-5}%, complex), 0.58 (1.2 x 10^{-5}%) daughter radiations from Th^{230}, Ra^{226}, Rn^{222}, etc.	daughter Pu^{238} descendant Th^{234} (HydE64)
$\underline{U^{235}}$ (AcU)	7.1 x 10^8 y sp act (FleE52, WhiP65) 7.1 x 10^8 y radiogenic Pb ratios (NierA39) 6.9 x 10^8 y sp act (DerA65) 6.8 x 10^8 y sp act (WurE57) $t_{1/2}$ (SF) 1.9 x 10^{17} y (SegE52) others (BaldE54)	☢ α, β stable (cons energy) (ForB58) % 0.7196 (GranB61) others (LouM56, WhiF56) Δ 40.93 (MTW) σ_c 101 (GoldmDT64) σ_f 577 (GoldmDT64)	A chem, mass spect (CuriM31) parent Th^{231} (UY)	α 4.58 (8%, doublet), 4.40 (57%), 4.37 (18%) γ Th X-rays, 0.143 (11%), 0.185 (54%), 0.204 (5%) daughter radiations from Th^{231}, etc.	natural source
U^{235m}	26.1 m (ShimS65) 26.5 m (AsaF57) 26.6 m* (HuiJ57a)	☢ IT (AsaF57, HuiJ57a) Δ 40.93 (LHP, MTW)	A genet (AsaF57) chem, genet (HuiJ57a) daughter Pu^{239} (AsaF57, HuiJ57a) not daughter Np^{235}, lim 2% (GinJ58)	e^- ≤0.0001 (100 eV)	daughter Pu^{239} (AsaF57, HuiJ57a)
U^{236}	2.39 x 10^7 y sp act (FleE52) 2.46 x 10^7 y sp act (JafAH51a) $t_{1/2}$ (SF) 2 x 10^{16} y (HydE57)	☢ α (GhiA51a) β stable (cons energy) (ForB58) Δ 42.46 (MTW) σ_c 6 (GoldmDT64)	A chem, n-capt, mass spect (GhiA51a)	α 4.49 (76%), 4.44 (24%) γ [Th L X-rays] e^- 0.032, 0.045	$U^{235}(n, \gamma)$ (HydE64)
U^{237}	6.75 d (WagF53) 6.63 d (MelaL48) others (WahA43, JameR49, ShermL58)	☢ β^- (NisY40a, MMilE40a) Δ 45.41 (MTW)	A chem, excit (NisY40a, MMilE40a) parent Np^{237} (WahA48) daughter Pu^{241} (SeaG49a)	β^- 0.248 max e^- 0.008, 0.011, 0.038, 0.089, 0.186 γ 0.026 (2%), 0.060 (36%), 0.165 (2.0%), 0.208 (23%), 0.267 (0.76%), 0.332 (1.4%, doublet), 0.370 (0.17%, doublet)	$U^{236}(n, \gamma)$ (RasJ57, YamaT66) $U^{238}(n, 2n)$ (MMilE40a, NisY40a, WahA48)
$\underline{U^{238}}$	4.51 x 10^9 y sp act (KovAF55, NierA39) others (KieC49, LeacR57) $t_{1/2}$ (SF): 6.5 x 10^{15} y sp act (KuzB59) 1.0 x 10^{16} y sp act (FleR64, KuroP56) 8.0 x 10^{15} y sp act (SegE52, SchaG46, ParkPL58) 5.8 x 10^{15} y sp act (GerlE59)	☢ α; β stable (cons energy) (ForB58) % 99.276 (WhiF56) others (LouM56) Δ 47.33 (MTW) σ_c 2.73 (GoldmDT64) σ_f <0.0005 (GoldmDT64)	A chem, genet, mass spect (CuriM31) parent Th^{234} (UX_1) (BecH1896)	α 4.20 (75%), 4.15 (25%) γ [Th L X-rays] e^- 0.030, 0.043 daughter radiations from Th^{234}, Pa^{234m}	natural source (HydE64)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12}=0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{92}U^{239}$	23.54 m (MitA43) 23.5 m (FeaN47a, MelaL47) others (IrvJ39, SeaG49)	☢ β^- (MMilE39) Δ 50.60 (MTW) σ_c 22 (GoldmDT64) σ_f 14 (GoldmDT64)	A n-capt (MeiL37) parent Np^{239} (MMilE40, StarK42)	β^- 1.29 max e^- 0.011, 0.023, 0.052, 0.069 γ Np L X-rays, 0.044 (4%), 0.075 (51%) daughter radiations from Np^{239}	$U^{238}(n, \gamma)$ (MeiL37, IrvJ39, MMilE39, StarK42)
U^{240}	14.1 h (KniJD53)	☢ β^- (KniJD53) Δ 52.74 (MTW)	A chem, n-capt (StuM49) parent Np^{240m} (KniJD53, HydE48a) daughter Pu^{244} (ButlJP56a, DiaH56)	β^- 0.36 max e^- 0.022, 0.038 γ Np L X-rays daughter radiations from Np^{240m}	$U^{238}(n, \gamma)U^{239}(n, \gamma)$ (HydE64)
$_{93}Np^{231}$	≈50 m (MagL50)	☢ α (MagL50) Δ 35.7 (MTW) EC unstable (cons energy) (MTW)	B chem, genet, excit, sep isotopes (MagL50) parent Pa^{227} (MagL50)	α 6.29 daughter radiations from Pa^{227} etc.	$U^{233}(d, 4n)$ (MagL50)
Np^{232}	≈13 m (MagL50)	☢ EC (MagL50) Δ 37 (MTW)	D chem (MagL50)	γ U X-rays, hard γ rays (MagL50)	$U^{235}(d, 5n)$, $U^{238}(d, 8n)$, $U^{233}(d, 3n)$ (MagL50)
Np^{233}	35 m (MagL50)	☢ EC 99+%, α ≈10^{-3}% (MagL50) Δ 38 (MTW)	B chem, excit, sep isotopes (MagL50)	α 5.54 γ U X-rays, γ rays observed	$U^{233}(d, 2n)$, $U^{235}(d, 4n)$ (MagL50)
Np^{234}	4.40 d (HydE49b) others (OsbD49)	☢ EC (OrtD51a) no α, lim 0.01% (HydE49b) β^+ ≈0.05% (PresRJ55) Δ 40.0 (MTW) σ_f ≈900 (GoldmDT64)	A chem, excit, genet, sep isotopes (JameR49) daughter Pu^{234} (PerlmI49, OrtD51a)	γ U X-rays, 0.109, 0.23, 0.25, 0.45, 0.50, 0.75, 0.95, 1.21, 1.56 (all radiations complex) e^- 0.024, 0.039, 0.696 β^+ 0.8 max	$U^{233}(d, n)$ (HydE64) $U^{235}(d, 3n)$ (HydE64) $U^{235}(p, 2n)$ (HydE64) $U^{233}(\alpha, p2n)$ (VanR58a, HydE64)
Np^{235}	410 d (JameR52) others (HydE49b)	☢ EC 99+%, α 1.6 x 10^{-3}% (GinJ58) others (HoffR56) Δ 41.05 (MTW)	A chem, excit, sep isotopes (JameR49) not parent U^{235m}, lim 2% (GinJ58)	γ U L X-rays, U K X-rays (weak) α 5.02	$U^{235}(d, 2n)$ (HydE64) daughter Pu^{235} (HydE64) $U^{233}(\alpha, pn)$ (VanR58a, HydE64) $U^{235}(\alpha, p3n)$ (HydE64)
Np^{236}	22 h (JameR49)	☢ EC 51%, β^- 49% (GinJ59a) EC(K)/β^- 0.75 (GrayP56) others (OrtD51) Δ 43.41 (MTW)	A chem, genet, sep isotopes, excit (JameR49) parent Pu^{236} (JameR49, JameR49a, HydE49b, GhiA52)	β^- 0.52 max e^- 0.025, 0.040 γ U X-rays, 0.642, 0.688	$U^{235}(d, n)$ (HydE64) $U^{235}(\alpha, p2n)$ (HydE64)
Np^{236}	$t_{1/2}(\beta^-)$ >5 x 10^3 y sp act (StuM55)	☢ β^- (?), no α observed (StuM55) σ_f 2500 (GoldmDT64)	A chem, mass spect (GinJ58, StuM55)		$U^{235}(d, n)$ (GinJ58, StuM55)
Np^{237}	2.14 x 10^6 y sp act (BrauF60) 2.2 x 10^6 y sp act (MagL48) $t_{1/2}$ (SF) >10^{18} y (DruV61a)	☢ α (WahA48); β stable (cons energy) (ForB58) Δ 44.89 (MTW) σ_c 170 (GoldmDT64) σ_f 0.019 (GoldmDT64)	A chem, genet, excit (WahA48) daughter U^{237} (WahA48) parent Pa^{233} (MagL47, HageF47)	α 4.78 (75%, complex), 4.65 (12%, doublet) γ Pa L X-rays, 0.030 (14%), 0.086 (14%), 0.145 (1%) e^- 0.009, 0.024, 0.036, 0.051, 0.067, 0.082 daughter radiations from Pa^{233}, U^{233}, etc.	$U^{238}(n, 2n)U^{237}(\beta^-)$ (WahA48)
Np^{238}	2.10 d (FreeM50) others (SeaG49, JameR49a)	☢ β^- (SeaG46, SeaG49) no EC(K), lim 1% (RasJ55a) EC unstable (cons energy) (MTW) Δ 47.47 (MTW) σ_f 1600 (GoldmDT64)	A chem, genet, n-capt, sep isotopes (SeaG46) parent Pu^{238} (SeaG46, KenJ49a, JafAH49, JameR49, SeaG46a) daughter Am^{242m} (SeaG49a, StreK50a, AsaF60)	β^- 1.25 max e^- 0.022, 0.039 γ 1.01 (42%, complex)	$Np^{237}(n, \gamma)$ (HydE64) $U^{238}(d, 2n)$ (SeaG46) $U^{238}(p, n)$ (MCorG54)
Np^{239}	2.346 d (WisL56) 2.37 d (CohD59) 2.34 d (ConnR59) others (PhiK46, DavD65, SeaG46, JameR49)	☢ β^- (MMilE40) Δ 49.32 (MTW) σ_c 25 (to Np^{240}) 35 (to Np^{240m}) (GoldmDT64) σ_f <1 (GoldmDt64)	A chem, n-capt, genet, excit (MMilE39, MMilE40) daughter U^{239} (MMilE40, StarK42) parent Pu^{239} (KenJ49, SeaG49) daughter Am^{243} (StreK50a)	β^- 0.713 max (11%), 0.437 max e^- 0.02-0.04, 0.048, 0.088, 0.106, 0.156 γ Pu X-rays, 0.106 (23%), 0.209 (4%), 0.228 (12%), 0.278 (14%)	$U^{238}(n, \gamma)U^{239}(\beta^-)$ (MMilE40, StarK42)

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$_{93}Np^{240}$	63 m (LesR60) others (OrtD51a)	☢ β^- (OrtD51a) Δ 52.2 (MTW)	A chem, cross bomb (OrtD51a) chem, mass spect (LesR60) not daughter Np^{240m}, lim 5% (LesR60)	β^- 0.89 max γ 0.16, 0.25, 0.44, 0.56, 0.60, 0.92, 1.00, 1.16	$U^{238}(\alpha, pn)$ (VanR58a, HydE64)
Np^{240m}	7.3 m (KniJD53, HydE48a)	☢ β^- (HydE48a) Δ 52.3 (LHP, MTW)	A chem, genet (HydE48a, KniJD53) daughter U^{240} (HydE48a, KniJD53) not parent Np^{240}, lim 5% (LesR60) descendant Pu^{244} (ButlJP56a, DiaH56)	β^- 2.16 max e^- 0.022, 0.038 γ 0.56 (21%), 0.60 (13%), 0.92 (3%, complex), 1.5 (3%, complex)	daughter U^{240} (HydE64)
Np^{241}	16 m (VanR59, LesR60)	☢ β^- (VanR59) Δ 54.3 (MTW)	A chem, mass spect (LesR60)	β^- 1.4 max	$U^{238}(\alpha, p)$ (VanR59, LesR60)
Np^{241}	3.4 h (LesR60)	☢ [β^-] (LesR60)	B chem, mass spect (LesR60)		$U^{238}(\alpha, p)$ (LesR60)
$_{94}Pu^{232}$	36 m (OrtD51a)	☢ α ≥2%, EC ≤98% (OrtD51a) Δ 38.4 (MTW)	B chem, sep isotopes, excit, genet (OrtD51a) parent U^{228} (OrtD51a, JameR48)	α 6.59 daughter radiations from Np^{232}, U^{228}, etc	$U^{233}(\alpha, 5n)$ (ThomT57) $U^{235}(\alpha, 7n)$ (HydE64)
Pu^{233}	20 m (ThomT57)	☢ EC 99+%, α 0.1% (ThomT57) Δ 40.04 (MTW)	B chem, excit, genet (ThomT57) parent U^{229} (ThomT57)	α 6.31 daughter radiations from Np^{233}, U^{229}, Th^{225}, etc.	$U^{233}(\alpha, 4n)$ (ThomT57)
Pu^{234}	9.0 h (OrtD51a) 8.5 h (PerlmI49) others (HigG52a)	☢ EC 94%, α 6% (AsaF57a) Δ 40.34 (MTW)	A chem, genet, sep isotopes, excit (HydE49b, PerlmI49) parent U^{230}, parent Np^{234} (PerlmI49, OrtD51a) daughter Cm^{238} (HigG52a)	α 6.20 (4%), 6.15 (1.9%) γ Np X-rays daughter radiations from Np^{234}, U^{230}, etc.	$U^{233}(\alpha, 3n)$ (VanR58a) $U^{235}(\alpha, 5n)$ (HydE64)
Pu^{235}	26 m (OrtD51a, ThomT57)	☢ EC 99+%, α 0.003% (ThomT57) Δ 42.2 (MTW)	B chem, excit, sep isotopes (OrtD51a, ThomT57)	γ Np X-rays α 5.86	$U^{235}(\alpha, 4n)$, $U^{233}(\alpha, 2n)$ (ThomT57, OrtD51a)
Pu^{236}	2.85 y (HoffD57) others (JameR49) $t_{1/2}$ (SF) 3.5×10^9 y (GhiA52)	☢ α (JameR49) β stable (cons energy) (ForB58) Δ 42.90 (MTW) σ_f 170 (GoldmDT64)	A chem, excit, sep isotopes, cross bomb, genet (JameR49) parent U^{232} (JameR49) daughter Cm^{240} (SeaG49b) daughter 22 h Np^{236} (JameR49, JameR49a, HydE49b, GhiA52)	α 5.77 (69%), 5.72 (31%) γ U L X-rays, 0.048 (0.31%), 0.109 (0.012%) e^- 0.028, 0.043 daughter radiations from U^{232}, etc.	daughter Np^{236} (HydE64) $U^{235}(\alpha, 3n)$ (VanR58a)
Pu^{237}	45.6 d (HoffD57a) 44 d (ThomT57) 40 d (HoffR53) others (JameR49a)	☢ EC 99+%, α 0.0033% (ThomT57) EC 99+%, α 0.002% (HoffD57a) Δ 45.12 (MTW) σ_f 2500 (GoldmDT64)	A chem, sep isotopes, cross bomb (JameR49) chem, genet energy levels (HoffD58) chem, mass spect (ThomT57)	γ Np X-rays, 0.060 (5%) e^- 0.026, 0.032, 0.038, 0.042, 0.056 α 5.66 (↑ 21), 5.37 (↑ 79)	$U^{235}(\alpha, 2n)$ (VanR58a) $Np^{237}(d, 2n)$ (JameR49a)
Pu^{237m}	0.18 s (StepF57a)	☢ IT (StepF57a) Δ 45.26 (MTW)	A genet (StepF57a) daughter Cm^{241} (StepF57a)	γ Pu L X-rays, 0.145 (2%) e^- 0.125 (75%), 0.140 (23%)	daughter Cm^{241} (StepF57a)
Pu^{238}	86.4 y genet (HoffD57b) others (SeaG49b, JafAH49) $t_{1/2}$ (SF) 4.9×10^{10} y (HydE57) others (DruV61a, SegE52)	☢ α (SeaG46) β stable (cons energy) (ForB58) Δ 46.18 (MTW) σ_c 500 (GoldmDT64) σ_f 16.8 (GoldmDT64)	A chem, sep isotopes, excit (SeaG46, SeaG46a, SeaG49) daughter Np^{238} (JameR49, JafAH49, SeaG46a, KenJ49a, SeaG46) daughter Cm^{242} (SeaG49b)	α 5.50 (72%), 5.46 (28%) γ U L X-rays, 0.099 (8×10^{-3}%), 0.150 (1×10^{-3}%), 0.77 (5×10^{-5}%, complex) e^- 0.024, 0.039	daughter Np^{238} from $Np^{237}(n, \gamma)$ (HydE64) daughter Cm^{242} (HydE64)
Pu^{239}	24,390 y sp act (DokY59) 24,413 y sp act (MarkT59) 24,181 y calorimeter (DetF65, StouJ47) others (FarwG54, CunB49) $t_{1/2}$ (SF) 5.5×10^{15} y (SegE52)	☢ α (KenJ49) β stable (cons energy) (ForB58) Δ 48.60 (MTW) σ_c 274 (GoldmDT64) σ_f 741 (GoldmDT64)	A chem, genet, mass spect (KenJ49) daughter Np^{239} (KenJ49, SeaG49) parent U^{235m} (AsaF57, HuiJ57a)	α 5.16 (88%, doublet), 5.11 (11%) γ U X-rays, 0.039 (0.007%), 0.052 (0.020%), 0.129 (0.005%), 0.375 (0.0012%), 0.414 (0.0012%), 0.65 (8×10^{-5}%, complex), 0.77 (2×10^{-5}%, doublet) e^- 0.008, 0.019, 0.033, 0.047	$U^{238}(n, \gamma)U^{239}(\beta^-)$ $Np^{239}(\beta^-)$ (KenJ49, SeaG49)

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$_{94}$Pu^{240}	6580 y genet (IngM51) others (DokY59, ButlJP56a, WestE51, FarwG54) $t_{1/2}$ (SF): 1.34 x 10^{11} y (WatD62b) 1.45 x 10^{11} y (MalkL63) others (BarcF54, ChambO54)	☢ α (JameR49) β stable (cons energy) (ForB58) Δ 50.14 (MTW) σ_c 286 (GoldmDT64) σ_f <0.08 (GoldmDT64)	A chem, n-capt, mass spect (ChambO44, FarwG46, BartlA44) daughter Cm^{244} (FrieA54)	α 5.17 (76%), 5.12 (24%) γ U L X-rays, 0.65 (complex, 2 x 10^{-5}%) e^- 0.026, 0.040	multiple n-capt from U^{238}, Pu^{239} (HydE64)
Pu^{241}	13.2 y (BrowF60) others (HallG56, MKenD53, RosB56, SmiH61, ThomS50d)	☢ β^- 99+%, α 2.3 x 10^{-3}% (BrowF60, SmiH61) others (AsaF57a, SeaG49a, GhiA50, IvaR63) Δ 52.98 (MTW) σ_c 425 (GoldmDT64) σ_f 950 (GoldmDT64)	A chem, n-capt, mass spect, excit, genet (SeaG49a, SeaG49, GhiA50) parent Am^{241} (SeaG49a, CunB49a) parent U^{237} (SeaG49a) daughter Cm^{245} (FrieA54)	β^- 0.021 max α 4.90 (0.0019%), 4.85 (0.0003%) γ U X-rays, 0.145 (1.6 x 10^{-4}%) daughter radiations from Am^{241}	multiple n-capt from U^{238}, Pu^{239}, etc. (HydE64)
Pu^{242}	3.79 x 10^5 y sp act (ButlJP56a) 3.73 x 10^5 y sp act (ButlJP56) others (MecJ56, ThomS50d) $t_{1/2}$ (SF): 7.1 x 10^{10} y (MecJ56) 7.4 x 10^{10} y (MalkL63) 6.6 x 10^{10} y (ButlJP56) others (DruV61a)	☢ α (ThomS50d) β stable (cons energy) (ForB58) Δ 54.74 (MTW) σ_c 19 (GoldmDT64) σ_f <0.2 (GoldmDT64)	A chem, mass spect, n-capt, genet (ThomS50d) daughter Am^{242} (AsaF60, OKelG50) daughter Cm^{246} (FrieA54)	α 4.90 (76%), 4.86 (24%) γ [U L X-rays]	multiple n-capt from U^{238}, Pu^{239}, etc. (HydE64) daughter Am^{242} (ButlJP56, HydE64)
Pu^{243}	4.98 h (EngeD53) others (SulJ51, ThomS51)	☢ β^- (SulJ51) Δ 57.77 (MTW) σ_c 170 (GoldmDT64)	A chem, n-capt, cross bomb (SulJ51) genet (ThomS51) parent Am^{243} (ThomS51)	β^- 0.58 max e^- 0.019, 0.036 γ Am L X-rays, 0.084 (21%), 0.381 (0.7%)	Pu^{242}(n, γ) (HydE64, SulJ51, ThomS51)
Pu^{244}	≈7.6 x 10^7 y genet (DiaH56) ≈7.5 x 10^7 y genet (ButlJP56a) $t_{1/2}$ (SF) 2.5 x 10^{10} y (FieP55a)	☢ [α] (StuM54a) β stable (cons energy) (ForB58) Δ 59.83 (MTW) σ_c 1.8 (GoldmDT64)	A chem, n-capt, mass spect, genet (StuM54a, ButlJP56a, DiaH56) ancestor Np^{240m}, parent U^{240} (ButlJP56a, DiaH56) daughter Am^{244m} (FieP55a)	α [4.58] daughter radiations from U^{240}, Np^{240m}	multiple n-capture from U^{238}, Pu^{239}, etc. (HydE64, EngeD55, StuM54a)
Pu^{245}	10.1 h (FieP55) 10.6 h genet (ButlJP56a) others (BrowCI55)	☢ β^- (FieP55) Δ 63 (MTW) σ_c ≈260 (GoldmDT64)	B chem, n-capt (FieP55, BrowCI55) parent Am^{245} (ButlJP56a, FieP55)	daughter radiations from Am^{245}	Pu^{244}(n, γ); multiple n-capt from U^{238}, Pu^{239}, etc. (HydE64, ButlJP56a)
Pu^{246}	10.85 d (HoffD56) others (EngeD55)	☢ β^- (EngeD55) Δ 65.3 (MTW)	A chem, n-capt, mass spect (EngeD55) parent Am^{246} (EngeD55)	β^- 0.33 max (10%), 0.15 max e^- 0.020, 0.038, 0.055, 0.156 γ Am X-rays, 0.044 (30%), 0.180 (10%), 0.224 (25%) daughter radiations from Am^{246}	multiple n-capt from U^{238} (EngeD55, HydE64)
$_{95}$Am^{237}	≈1.3 h (HigG52a)	☢ EC 99+%, α 0.005% (HigG52a) Δ 47 (MTW)	B chem, excit (HigG52a)	α 6.02	Pu^{239}(p, 3n), Pu^{239}(d, 4n) (HigG52a)
Am^{238}	1.9 h (GlasR60) others (HigG52a)	☢ EC (StreK50a) no α, lim 3 x 10^{-4}% (HigG52a) Δ 48 (MTW)	B chem, excit (StreK50a)	γ Pu X-rays, 0.36 (12%), 0.58 (29%), 0.98 (80%, doublet), 1.35 (76%)	Pu^{239}(p, 2n) (GlasR60) Pu^{239}(d, 3n) (StreK50a, HydE64) Np^{237}(α, 3n) (HydE64)
Am^{239}	12.1 h (GlasR60) 12 h (SeaG49a)	☢ EC 99+%, α 0.005% (GlasR60) EC 99+%, α 0.003% (HigG52a) Δ 49.41 (MTW)	A chem, excit (SeaG49a) genet energy levels (SmiW57) daughter Bk^{243} (ThomS50b)	γ Pu X-rays, 0.209 (5%), 0.228 (18%, doublet), 0.278 (17%) e^- 0.02-0.04, 0.048, 0.088, 0.106, 0.156 α 5.78	Pu^{239}(p, n) (StreK50a) Pu^{239}(d, 2n) (GlasR60, HigG52a, SeaG49a) Np^{237}(α, 2n) (SeaG49a)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12} = 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{95}\mathrm{Am}^{240}$	51.0 h (GlasR60) others (SeaG49a)	☢ EC (SeaG49a) no α, lim 0.2% (HigG52a) Δ 51 (MTW)	A chem, excit (SeaG49) chem, excit, cross bomb (StreK50a) genet energy levels (SmiW57)	γ Pu X-rays, 0.90 (23%), 1.00 (77%) e^- 0.022, 0.038, 0.079, 0.094	Pu^{239}(d, n) (StreK50a) Pu^{239}(α, p2n) (GlasR56, VanR58) Np^{237}(α, n) (StreK50a, HydE64)
Am^{241}	458 y sp act (HallG57, WallJ58, HallG56) others (HarvB52) $t_{1/2}$ (SF) 2 x 10^{14} y (DruV61) others (MikV59)	☢ α (SeaG49a) β stable (cons energy) (ForB58) Δ 52.96 (MTW) σ_c 700 (to Am^{242}) 100 (to Am^{242m}) (GoldmDT64) σ_f 3.0 (GoldmDT64)	A chem, n-capt, excit, mass spect (SeaG49a) daughter Pu^{241} (SeaG49a, CunB49a)	α 5.49 (85%), 5.44 (13%) γ Np L X-rays, 0.060 (36%), 0.101 (0.04%, complex), 0.208 (6 x 10^{-4}%), 0.335 (8 x 10^{-4}%, complex), 0.37 (4 x 10^{-4}%, complex), 0.663 (5 x 10^{-4}%), 0.722 (3 x 10^{-4}%) e^- 0.022, 0.038, 0.054	daughter Pu^{241} (HydE64)
Am^{242}	16.01 h (KeeT53) others (BaranS55, SeaG49b)	☢ β^- 84%, EC 16% (HoffR59) others (BarnR59, HoffR55, BaranS55) Δ 55.48 (MTW) σ_f 2900 (GoldmDT64)	A chem, n-capt, genet (MannWM49, SeaG49b) parent Cm^{242} (MannWM49, SeaG49b, AsaF60) parent Pu^{242} (OKelG50, AsaF60) daughter Am^{242m} (AsaF60)	β^- 0.67 max e^- 0.021, 0.037 γ Pu X-rays, Cm L X-rays	Am^{241}(n, γ), or multiple n-capt from U^{238}, Pu^{239}, etc (HydE64)
Am^{242m}	152 y (BarnR59) others (StreK50a)	☢ IT 99+%, α 0.48% (BarnR59, AsaF60) Δ 55.52 (LHP, MTW) σ_c 2000 (GoldmDT64) σ_f 6000 (GoldmDT64)	A chem, mass spect, n-capt (SeaG49a, StreK50a) parent Am^{242} (AsaF60) parent Np^{238} (SeaG49a, StreK50a, AsaF60)	α 5.21 (0.41%) e^- 0.028, 0.044 γ Am L X-rays, Np X-rays, 0.049 (0.20%), 0.087 (0.036%), 0.110 (0.025%), 0.163 (0.025%) daughter radiations from Am^{242}, Np^{238}	Am^{241}(n, γ) (SeaG49a, MannWM49, AsaF60)
Am^{243}	7.95 x 10^3 y sp act (WallJ58) 7.65 x 10^3 y sp act (BeadA60) others (BarnR59, ButlJP57, HulE57, AsaF54, DiaH53)	☢ α (StreK50a) β stable (cons energy) (ForB58) Δ 57.18 (MTW) σ_c 74 (GoldmDT64) σ_f <0.07 (GoldmDT64)	A chem, mass spect (StreK50a) parent Np^{239} (StreK50a) daughter Pu^{243} (ThomS51)	α 5.28 (87%), 5.23 (11.5%) γ Np L X-rays, 0.044 (4%), 0.075 (50%) e^- [0.011, 0.023, 0.052, 0.069] daughter radiations from Np^{239}	multiple n-capt from U^{238}, Pu^{239}, etc. (HydE64, StreK50a)
Am^{244}	10.1 h (VanS62)	☢ β^- (VanS62) Δ 59.90 (MTW) σ_f 2300 (GoldmDT64)	A chem, n-capt, sep isotopes, genet (VanS62) parent Cm^{244} (VanS62)	β^- 0.387 max e^- 0.020, 0.037, 0.077, 0.094 γ Cm X-rays, 0.099 (5%), 0.154 (19%), 0.746 (66%), 0.900 (25%)	Am^{243}(n, γ) (VanS62)
Am^{244m}	26 m (GhiA54a)	☢ β^- 99+%, EC 0.039% (FieP55a) Δ 60.02 (LHP, MTW)	A chem, n-capt (StreK50a) chem, genet (FieP55a) parent Cm^{244} (ReynF50, FieP55a) parent Pu^{244} (FieP55a)	β^- 1.50 max e^- 0.020, 0.037 γ Cm L X-rays	Am^{243}(n, γ) (StreK50a)
Am^{245}	2.07 h (ButlJP56a) others (BrowCI55, FieP55)	☢ β^- (BrowCI55, FieP55) Δ 61.93 (MTW)	B chem, genet (BrowCI55, FieP55) daughter Pu^{245} (FieP55, ButlJP56a)	β^- 0.91 max e^- 0.125 γ Cm X-rays, 0.253	daughter Pu^{245} (ButlJP56a, FieP55, BrowCI55, HydE64)
Am^{246}	25.0 m (EngeD55) others (BrowCI55)	☢ β^- (EngeD55, BrowCI55) Δ 64.9 (MTW)	A chem, genet (BrowCI55, EngeD55) parent Cm^{246} (BrowCI55) daughter Pu^{246} (EngeD55)	β^- 2.10 max (7%), 1.60 max γ Cm X-rays, 0.799 (29%), 1.07 (65%, complex)	daughter Pu^{246} (EngeD55, HydE64)
$_{96}\mathrm{Cm}^{238}$	2.5 h (StreK48)	☢ EC <90%, α >10% (CarrR52) Δ 49.39 (MTW)	B chem (StreK48) chem, genet (HigG52a) parent Pu^{234} (HigG52a)	α 6.51 daughter radiations from Pu^{234}	Pu^{239}(α, 5n) (GlasR56, StreK48) Pu^{238}(α, 4n) (GlasR56)
Cm^{239}	2.9 h (VanR58) 3 h (CarrR52)	☢ EC, no α (lim 0.1%) (CarrR52) Δ 51 (MTW)	B chem, excit (CarrR52) chem, genet energy levels (VanR58)	γ Am X-rays, 0.188 daughter radiations from Am^{239}	Pu^{239}(α, 4n) (CarrR52)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV (C^{12} = 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{96}Cm^{240}$	26.8 d (SeaG49b) $t_{1/2}$ (SF) 7.9 x 10^5 y (GhiA52)	☢ α (SeaG49b) no EC, lim 0.5% (HigG52) Δ 51.72 (MTW)	A chem, genet (SeaG49b) parent Pu^{236} (SeaG49b) daughter Cf^{244} (ChetA56)	α 6.29 (72%), 6.25 (28%) daughter radiations from Pu^{236}	Pu^{239}(α, 3n) (GlasR56)
Cm^{241}	35 d (HigG52)	☢ EC 99%, α 1.0% (GlasR56) Δ 53.73 (MTW)	A chem, excit, cross bomb (SeaG49b, HigG52, GlasR59) parent Pu^{237m} (StepF57a)	γ Am X-rays, 0.475 (95%), 0.60 e^- 0.123, 0.350 α 5.94 daughter radiations from Pu^{237} daughter radiations from Pu^{237m} included in above listing	Pu^{239}(α, 2n) (GlasR56)
Cm^{242}	162.5 d (GloK54, HannG50) 164.4 d (FlyK65a) others (HutWP54) $t_{1/2}$ (SF) 7.2 x 10^6 y (HannG51)	☢ α (SeaG49b) β stable (cons energy) (ForB58) Δ 54.82 (MTW) σ_c 20 (GoldmDT64) σ_f <5 (GoldmDT64)	A chem, genet (SeaG49b) mass spect (ReynF50) daughter Am^{242} (AsaF60, MannWM49, SeaG49b) daughter Cf^{246} (HulE51) parent Pu^{238} (SeaG49b)	α 6.12 (74%), 6.07 (26%) γ Pu L X-rays, 0.044 (0.041%), 0.102 (4 x 10^{-3}%), 0.158 (2.5 x 10^{-3}%), 0.58 (3.2 x 10^{-4}%, complex), 0.89 (3 x 10^{-5}%) e^- 0.022, 0.039 daughter radiations from Pu^{238}	daughter Am^{242m}, from Am^{241}(n, γ), or multiple n-capt from U^{238}, Pu^{239}, etc. (HydE64)
Cm^{243}	32 y sp act + mass spect (AsaF57a, HydE64) others (ThomS50b)	☢ α (ReynF50) EC 0.3% (ChoG58) Δ 57.19 (MTW) σ_c 250 (GoldmDT64) σ_f 660 (GoldmDT64)	A chem, mass spect, genet (ReynF50) daughter Bk^{243} (ThomS50b)	α 6.06 (6%, doublet), 5.99 (6%, doublet), 5.79 (73%), 5.74 (11.5%) γ Pu X-rays, 0.209 (4%), 0.228 (12%), 0.278 (14%) e^- 0.02-0.04, 0.048, 0.088, 0.106, 0.156	multiple n-capt from U^{238}, Pu^{239}, etc. (HydE64, ReynF50)
Cm^{244}	17.6 y sp act + mass spect (CarnW61) others (FrieA54, StevC54) $t_{1/2}$ (SF) 1.31 x 10^7 y (MetD65) 1.46 x 10^7 y (MalkL63a) others (GhiA52)	☢ α (ReynF50) β stable (cons energy) (ForB58) Δ 58.47 (MTW) σ_c 15 (GoldmDT64)	A chem, mass spect (ReynF50) daughter Am^{244m} (ReynF50, FieP55a) daughter Am^{244} (VanS62) daughter Bk^{244} (GuseL56, ChetA56b) daughter Cf^{248} (HulE54) parent Pu^{240} (FrieA54)	α 5.81 (77%), 5.77 (23%) γ Cm L X-rays, 0.043 (0.02%), 0.100 (0.0015%), 0.150 (0.0013%), 0.262 (1.4 x 10^{-4}%), 0.59 (2.5 x 10^{-4}%, doublet), 0.82 (7 x 10^{-5}%) e^- 0.022, 0.038	multiple n-capt from U^{238}, Pu^{239}, Am^{243} etc. (HydE64)
Cm^{245}	9.3 x 10^3 y genet, mass spect (CarnW61) others (HuiJ57b, BrowCI55, FrieA54)	☢ α (HulE51) β stable (cons energy) (ForB58) Δ 61.02 (MTW) σ_c 200 (GoldmDT64) σ_f 1900 (GoldmDT64)	A chem, decay charac, genet (HulE51) chem, mass spect (StevC54, HulE54) daughter Bk^{245} (HulE54, HulE51) parent Pu^{241} (FrieA54)	α 5.36 (80%), 5.31 (7%) γ Pu X-rays, 0.13 (5%), 0.173 (14%) daughter radiations from Pu^{241}, Am^{241}	multiple n-capt from U^{238}, Pu^{239}, Am^{243}, Cm^{244}, etc. (StevC54, FieP56) daughter Bk^{245} (HulE51, HulE54) (HydE64)
Cm^{246}	5.5 x 10^3 y genet (CarnW61) others (ButlJP56b, BrowCI55, FrieA54) $t_{1/2}$ (SF) 1.7 x 10^7 y (MetD65) others (FrieS56)	☢ α (FrieA54, StevC54) β stable (cons energy) (ForB58) Δ 62.64 (MTW) σ_c 15 (GoldmDT64)	A chem, mass spect (StevC54, FieP56) parent Pu^{242} (FrieA54) daughter Am^{246} (BrowCI55) daughter Cf^{250} (ButlJP56b)	α 5.39 (81%), 5.34 (19%) γ [Pu L X-rays]	multiple n-capt from U^{238}, Pu^{239}, Cm^{244}, etc. (HydE64, StevC54, FieP56) daughter Cf^{250} (ButlJP56b)
Cm^{247}	$t_{1/2}$ (α) 1.6 x 10^7 y genet + mass spect (FieP63) $t_{1/2}$ (α) >4 x 10^7 y genet + mass spect (DiaH57, StevC54)	☢ [α] (DiaH57, StevC54) Δ 65.56 (MTW) σ_c 180 (GoldmDT64)	A chem, mass spect (StevC54, DiaH57) daughter Cf^{251} (EasT57)		multiple n-capt from U^{238}, Pu^{239}, Cm^{244}, etc. (HydE64, DiaH57, StevC54)
Cm^{248}	4.7 x 10^5 y sp act (ButlJP56b) $t_{1/2}$ (SF) 4.6 x 10^6 y (ButlJP56b)	☢ α 89%, SF 11% (ButlJP56b) β stable (cons energy) (ForB58) Δ 67.43 (MTW) σ_c 6 (GoldmDT64)	B chem, genet (ButlJP56b) daughter Cf^{252} (ButlJP56b)	α 5.08 (82%), 5.04 (18%) γ [Pu L X-rays] SF fission fragments, neutrons, γ rays, electrons, daughter radiations	daughter Cf^{252} (ButlJP56b) multiple n-capt from U^{238}, Pu^{239}, Cm^{244}, etc. (HydE64)
Cm^{249}	64 m (EasT58) 65 m (FieP56)	☢ β^- (FieP56) Δ 70.8 (MTW)	B n-capt, chem (FieP56)	β^- 0.9 max	Cm^{248}(n, γ) (EasT58) multiple n-capt from U^{238}, Pu^{239}, Cm^{244}, etc. (ThomS54, FieP56, HydE64)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}=0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{96}\text{Cm}^{250}$	$t_{1/2}$ (SF): 1.7 x 10^4 y (GrouCR66) 2 x 10^4 y (HuiJ57b) others (FieP56)	☢ SF (HuiJ57b) Δ 73 (MTW)	A chem, decay charac (HuiJ57b) chem, mass spect (GrouCR66)	SF fission fragments, neutrons, γ rays, electrons, daughter radiations	multiple n-capt from U^{238} (HuiJ57b, HydE64)
$_{97}\text{Bk}^{243}$	4.6 h (ThomS50b, GhiA54) 4.5 h (ChetA56b) others (HulE51)	☢ EC 99+%, α 0.15% (ChetA56b) Δ 58.70 (MTW)	A chem, genet (ThomS50, ThomS50b) parent Cm^{243} (ThomS50b) parent Am^{239} (ThomS50b)	α 6.76 (0.023%), 6.72 (0.019%), 6.57 (0.038%), 6.54 (0.029%), 6.21 (0.020%) γ Cm X-rays, 0.755, 0.84, 0.946	$Am^{241}(\alpha, 2n)$ (ThomS50b) $Cm^{242}(d, n)$ (HulE51) $Am^{243}(\alpha, 4n)$ (ChetA56b) (HydE64)
Bk^{244}	4.4 h (ChetA56b)	☢ EC 99+%, α 0.006% (ChetA56b) Δ 61 (MTW)	B chem, excit, genet (ChetA56b) parent Cm^{244} (ChetA56b, GuseL56)	α 6.67 (0.003%), 6.62 (0.003%) γ Cm X-rays, 0.145 (I 7), 0.188 (I 16), 0.218 (I 100), 0.334 (I 10), 0.490 (I 14), 0.892 (I 88), 0.922 (I 17), 1.16 (I 11, doublet)	$Am^{243}(\alpha, 3n)$ (ChetA56b) $[Cm^{244}(d, 2n)]$, $[Cm^{244}(p, n)]$, $Am^{241}(\alpha, n)$ (HydE64)
Bk^{245}	4.98 d (MagL56) others (HulE51)	☢ EC 99+%, α 0.11% (MagL56) Δ 61.84 (MTW)	A chem, excit, decay charac (HulE51) daughter Cf^{245} (ChetA56) parent Cm^{245} (HulE51, HulE54)	α 6.36 (0.018%), 6.32 (0.017%), 6.15 (0.021%), 6.12 (0.016%), 5.89 (0.024%) γ Cm X-rays, 0.253 (31%), 0.39 (3%, doublet) e^- 0.125	$Am^{243}(\alpha, 2n)$ (ChetA56b) $Cm^{244}(d, n)$ (HulE51) $Cm^{242}(\alpha, p)$ (HulE51) (HydE64)
Bk^{246}	1.8 d (HulE54)	☢ EC (HulE54) Δ 64 (MTW)	B chem, decay charac, excit (HulE54, ChetA56b)	γ Cm X-rays, 0.800 (40%), 1.07 (12%, complex)	$Cm^{244}(\alpha, pn)$, $Am^{243}(\alpha, n)$ (HulE54, ChetA56b, HydE64)
Bk^{247}	1.4 x 10^3 y (MilsJ65) others (ChetA56b)	☢ α, no EC (ChetA56b) Δ 65.47 (MTW)	B chem, decay charac (ChetA56b)	α 5.68 (37%), 5.52 (58%) γ Am X-rays, 0.084 (40%), 0.27 (30%) daughter radiations from Am^{243} etc.	daughter Cf^{247}, $Cm^{244}(\alpha, p)$, $Cm^{245-6}(\alpha, pxn)$ (HydE64, ChetA56b)
Bk^{248}	16 h (ChetA56b) 23 h genet (HulE56)	☢ β^- 70%, EC 30% (ChetA56b) Δ 67.9 (MTW)	B n-capt, chem, genet (ChetA56b) parent Cf^{248} (HulE56, ChetA56b)	β^- 0.65 max γ Cm X-rays daughter radiations from Cf^{248}	$Bk^{247}(n, \gamma)$ (ChetA56b) $Cm^{245}(\alpha, p)$ (HulE56) (HydE64)
Bk^{248}	>9 y sp act + mass spect (MilsJ65) $t_{1/2}$ (β^-) >10^4 y genet (MilsJ65)	☢ ?	B chem, mass spect (MilsJ65)		$Cm^{246}(\alpha, pn)$ (MilsJ65)
Bk^{249}	314 d (EasT57) others (MagL54, DiaH54) $t_{1/2}$ (SF): 6 x 10^8 y (HydE57) >1.5 x 10^9 y (EasT57)	☢ β^- 99+%, α 0.0022% (EasT57) others (MagL54, DiaH54) Δ 69.86 (MTW) σ_c 500 (GoldmDT64)	A chem, genet (ThomS54, GhiA54a, DiaH54) chem, mass spect (FieP56) parent Cf^{249} (GhiA54a, MagL54)	β^- 0.125 max α 5.42 (0.0015%) γ 0.32 (3 x 10^{-5}%, doublet) daughter radiations from Cf^{249}, Am^{245}	multiple n-capt from U^{238}, Pu^{239}, Cm^{244}, etc. (ThomS54, DiaH54, MagL54, FieP56, HydE64)
Bk^{250}	193.3 m (VanS59) others (GhiA54a, MagL54)	☢ β^- (GhiA54a) Δ 72.95 (MTW)	A n-capt, chem, genet (GhiA54a) parent Cf^{250} (GhiA54a) daughter Es^{254} (HarvB55, JonM56)	β^- 1.76 max (11%), 0.73 max e^- 0.019, 0.036 γ Cf L X-rays, 0.990 (47%), 1.032 (39%)	$Bk^{249}(n, \gamma)$ (GhiA54a) daughter Es^{254} (HarvB55, JonM56) (HydE64)
$_{98}\text{Cf}^{244}$	25 m (ChetA56) others (ThomS50c, ThomS50a, GhiA51, GhiA54, GuseL56)	☢ α (ChetA56) Δ 61.43 (MTW)	A chem, excit, genet (ThomS50a, ChetA56) parent Cm^{240} (ChetA56) daughter Fm^{248} (GhiA58)	α 7.18	$Cm^{244}(\alpha, 4n)$ (ChetA56) $Cm^{242}(\alpha, 2n)$ (ChetA56) $U^{238}(C^{12}, 6n)$ (HydE64)
Cf^{245}	44 m (ThomS50c) others (ThomS50a, GhiA51, GhiA54)	☢ EC 70%, α 30% (ChetA56) Δ 63.38 (MTW)	B chem, excit, genet (ChetA56) parent Bk^{245} (ChetA56) not parent Cm^{240} (ChetA56) daughter Fm^{249} (PerelV59)	α 7.12 daughter radiations from Bk^{245} Cm^{241}	$Cm^{244}(\alpha, 3n)$ (ChetA56) $Cm^{242}(\alpha, n)$ (ChetA56) $U^{238}(C^{12}, 5n)$ (GhiA51, GhiA54) (HydE64)
Cf^{246}	35.7 h (HulE51) $t_{1/2}$ (SF) 2.1 x 10^3 y (HulE53)	☢ α (GhiA51) Δ 64.11 (MTW)	A chem, genet (GhiA51) parent Cm^{242} (HulE51) daughter Es^{246} (GhiA54)	α 6.76 (78%), 6.72 (22%) γ Cm L X-rays daughter radiations from Cm^{242}	$Cm^{244}(\alpha, 2n)$ (ChetA56, HulE51) $U^{238}(C^{12}, 4n)$ (GhiA51) (HydE64)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (△≡M–A), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{98}$Cf^{247}	2.5 h (HulE54, ChetA56b) others (GhiA54)	☢ EC (HulE54) Δ 66 (MTW)	B chem (HulE54) chem, excit (ChetA56b)	γ Bk X-rays, 0.295 (1%), 0.417, 0.460 e$^-$ 0.164	Cm^{244}(α, n) (HulE54) Cm$^{245-6}$(α, xn) (HydE64) U^{238}(N^{14}, p4n) (GhiA54)
Cf^{248}	350 d genet (HulE57a) others (GhiA54) t$_{1/2}$ (SF) ≥1.5 x 10^4 y (HulE57a)	☢ α (GhiA54, HulE54) β stable (cons energy) (ForB58) Δ 67.26 (MTW)	A chem, genet (GhiA54, (HulE54) parent Cm^{244} (HulE54) daughter 16 h Bk^{248} (HulE56, ChetA56b) daughter Fm^{252} (FrieA56) daughter Es^{248} (ChetA56a)	α 6.27 (82%), 6.22 (18%) γ [Cm L X-rays]	Cm$^{245-248}$(α, xn) (HulE54) U^{238}(N^{14}, p3n) (GhiA54) daughter Bk^{248}, Es^{248}, Fm^{252} (HydE64)
Cf^{249}	360 y genet (EasT57) others (MagL54, GhiA54a) t$_{1/2}$ (SF): 1.5 x 10^9 y (HydE57) others (DiaH54, MagL54)	☢ α (ThomS54) β stable (cons energy) (ForB58) Δ 69.74 (MTW) σ$_c$ 270 (GoldmDT64) σ$_f$ 1735 (GoldmDT64)	A chem, genet (ThomS54, GhiA54a) chem, genet, mass spect (DiaH54, MagL54, FieP56) daughter Bk^{249} (GhiA54a, MagL54)	α 5.81 (84%) γ Cm X-rays, 0.333 (16%), 0.388 (72%)	daughter Bk^{249} (GhiA54a, DiaH54, MagL54, HydE64) multiple n-capt from U^{238}, Pu^{239}, Cm^{244}, etc. (HydE64)
Cf^{250}	13.2 y genet (MetD65) 13 y (PhiL63) others (EasT57, MagL54, GhiA54a) t$_{1/2}$ (SF) 1.7 x 10^4 y (MetD65, PhilL63) others (MagL54, DiaH54, GhiA54a)	☢ α (GhiA54a) β stable (cons energy) (ForB58) Δ 71.19 (MTW) σ$_c$ 1500 (GoldmDT64) σ$_f$ <350 (GoldmDT64)	A chem, genet (ThomS54, GhiA54a) chem, mass spect (DiaH54, MagL54) daughter Bk^{250} (GhiA54a) daughter Fm^{254} (PhiL63) parent Cm^{246} (ButlJP56b)	α 6.03 (83%), 5.99 (17%) e$^-$ 0.023, 0.038 γ [Cm L X-rays]	multiple n-capt from U^{238}, Pu^{239}, Cm^{244}, etc. (MagL54) daughter Bk^{250} (GhiA54a, PhiL63) daughter Fm^{254} (LedC63) (HydE64)
Cf^{251}	≈800 y genet (EasT57) others (MagL54)	☢ α (EasT57) β stable (cons energy) (ForB58) Δ 74.15 (MTW) σ$_c$ 3000 (GoldmDT64) σ$_f$ 3000 (GoldmDT64)	A chem, mass spect (DiaH54, MagL54) parent Cm^{247} (EasT57)	α 5.85 (45%), 5.67 (55%) γ Cm X-rays, 0.18	multiple n-capt from U^{238}, Pu^{239}, Cm^{244}, etc. (EasT57, MagL54, DiaH54, HydE64)
Cf^{252}	2.646 y (MetD65) others (MagL54, EasT57, FieP56, GhiA54a) t$_{1/2}$ (SF): 85 y (MetD65) others (GhiA54a, EasT57, MagL54, SevK61)	☢ α 96.9%, SF 3.1% (MetD65) α 97.0%, SF 3.0% (AsaF66a) β stable (cons energy) (ForB58) Δ 76.05 (MTW) σ$_c$ 30 (GoldmDT64)	A chem (ThomS54, GhiA54a) chem, mass spect (StuM54, MagL54, DiaH54) parent Cm^{248} (ButlJP56b)	α 6.12 (82%), 6.08 (15%) e$^-$ 0.022, 0.038 γ Cm L X-rays SF fission fragments, neutrons, γ rays, electrons, daughter radiations	multiple n-capt from U^{238}, Pu^{239}, Cm^{244}, etc. (GhiA54, DiaH54, MagL54, FieP56, HydE64)
Cf^{253}	17.6 d genet (MetD65) 17 d genet (EasT57) 18 d (DiaH54, MagL54) others (ChoG54)	☢ β$^-$ 99+%, α 0.31% (GrouCR66) Δ 79.3 (MTW)	A chem, genet (ChoG54, DiaH54, MagL54) chem, mass spect (FieP56) parent Es^{253} (ChoG54, MagL54) [daughter Fm^{257}] (HulE64)	β$^-$ 0.27 max α 5.98 daughter radiations from Es^{253}	multiple n-capt from U^{238}, Pu^{239}, Cm^{244}, Cf^{252}, etc. (MagL54, ThomS54, ChoG54, HydE64)
Cf^{254}	60.5 d (PhiL63, MetD65) others (HuiJ57b, FieP56, HarvB55)	☢ SF 99+%, α ≈0.2% (AsaF66a) β stable (cons energy) (ForB58) Δ 81 (MTW) σ$_c$ <2 (GoldmDT64)	A chem, genet (HarvB55) chem, mass spect (FieP56) daughter Es^{254m} (HarvB55, FieP56) not daughter Fm^{257} (HulE64)	SF fission fragments, neutrons, γ rays, electrons, daughter radiations α 5.84	multiple n-capt from U^{238}, Pu^{239}, Cm^{244}, Cf^{252}, etc. (FieP56, DiaH60) daughter Es^{254m} (0.08%) (HarvB55, FieP56) (HydE64)
$_{99}$Es^{245}	1.3 m (GhiA61a, MikV66)	☢ α 17%, EC 83% (MikV66) Δ 66 (MTW)	B cross bomb (GhiA61a) cross bomb, excit, genet (MikV66) parent Cf^{245} (MikV66)	α 7.70 daughter radiations from Cf^{245}	U^{235}(N^{14}, 4n), U^{238}(N^{14}, 7n) (MikV66) Np^{237}(C^{12}, 4n), Pu^{240}(B^{10}, 5n) (GhiA61a)
Es^{246}	7.3 m (GhiA54) 7.7 m (MikV66) others (GuseL56)	☢ α 10%, EC 90% (MikV66) Δ 68 (MTW)	D chem, decay charac, genet (GhiA54) excit, genet (MikV66) parent Cf^{246} (GhiA54, MikV66)	α 7.33	U^{238}(N^{14}, 6n) (GhiA54, MikV66, HydE64)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess ($\Delta \equiv M-A$), MeV ($C^{12} \equiv 0$); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{99}\mathrm{Es}^{247}$	5.0 m (MikV66)	☢ α ≈7%, EC ≈93% (MikV66) Δ 68 (MTW)	C excit (MikV66)	α 7.33	$\mathrm{U}^{238}(\mathrm{N}^{14}$, 5n) (MikV66)
Es^{248}	25 m (ChetA56a)	☢ EC 99+%, α ≈0.3% (ChetA56a) Δ 70 (MTW)	B chem, excit, genet (ChetA56a) parent Cf^{248} (ChetA56a)	α 6.88	Cf^{249}(d, 3n) (ChetA56a) (HydE64)
Es^{249}	2 h (HarvB56)	☢ EC 99+%, α 0.13% (HarvB56) Δ 71.15 (MTW)	B chem, excit (HarvB56)	α 6.77	Bk^{249}(α, 4n) (HarvB56) Cf^{249}(d, 2n) (ChetA56a) Cf^{249}(α, p3n) (HarvB56) (HydE64)
Es^{250}	8 h (HarvB56)	☢ EC (HarvB56) Δ 73 (MTW)	B chem, excit (HarvB56)	γ [Cf X-rays]	Bk^{249}(α, 3n), Cf^{249}(d, n), Cf^{249}(α, t) (HydE64)
Es^{251}	1.5 d (HarvB56)	☢ EC 99+%, α 0.53% (HarvB56) Δ 74.5 (MTW)	B chem, excit (HarvB56)	α 6.49	Bk^{249}(α, 2n) (HarvB56)
Es^{252}	≈140 d (HarvB56)	☢ α, no β^-, lim 3%, no EC (HarvB56) EC and β^- unstable (cons energy) (MTW) Δ 77.1 (MTW)	B chem, excit (HarvB56)	α 6.64 (82%), 6.58 (13%) γ Bk X-rays, 0.074 (0.07%), 0.154 (0.07%), 0.198 (0.08%), 0.228 (0.23%), 0.278 (0.21%), 0.40 (1.1%, complex)	Bk^{249}(α, n) (HarvB56) Cf^{252}(d, 2n) (MHarW65)
Es^{253}	20.47 d (HalvS66) 20.7 d (GrouCR66) 20.03 d (JonM56) others (FieP54, ChoG54) $t_{1/2}$ (SF): 6.4 x 10^5 y (MetD65) 7 x 10^5 y (JonM56) others (FieP54, StuM54)	☢ α (ThomS54) β stable (cons energy) (ForB58) Δ 79.03 (MTW) σ_c 300 (to Es^{254m})	A chem, genet (ThomS54, ChoG54, StuM54) daughter Cf^{253} (ChoG54, MagL54) daughter Fm^{253} (AmiS57) descendant Fm^{257} (SikT65)	α 6.64 (90%) e^- 0.017, 0.027, 0.035, 0.040 γ Bk X-rays, 0.387 (0.05%, complex), 0.429 (0.008%, doublet)	daughter Cf^{253} (from multiple n-capt) (JonM56, StuM54, ThomS54, HydE64)
Es^{254}	276 d (UniJ66) 480 d (SchumR58, JonM56) others (HarvB55) $t_{1/2}$ (SF) 7 x 10^5 y (MHarW65)	☢ α, no β^-, lim 3 x 10^{-4}% (MHarW66) Δ 82.00 (MTW) σ_c <40 (GoldmDT64)	A chem, genet (HarvB55, JonM56) parent Bk^{250} (HarvB55, JonM56) not parent Fm^{254}, lim 3 x 10^{-4}% (MHarW66)	α 6.44 (93%) γ Bk X-rays, 0.063 (2.0%), 0.27 (0.12%, complex), 0.31 (0.22%, doublet), 0.39 (0.07%, complex) e^- 0.011, 0.018, 0.030, 0.037 daughter radiations from Bk^{250}, Cf^{250}	multiple n-capt from U^{238}, Pu^{239}, Cm^{244}, Cf^{252}, Es^{253}, etc. (JonM56, HarvB55, HydE64)
Es^{254m}	39.3 h (UniJ62) others (FieP54, JonM56, ChoG54) $t_{1/2}$ (SF) >10 y (FieP54)	☢ β^- 99+%, EC 0.08% (PhiL63) others (HarvB55) Δ 82.10 (MTW)	A n-capt, chem, decay charac (FieP54, ChoG54, HarvB55) parent Fm^{254} (FieP54, ChoG54) parent Cf^{254} (HarvB55, FieP56)	β^- 1.13 max (25%), 0.43 max e^- 0.020, 0.038 γ Fm X-rays, 0.65 (31%), 0.69 (38%, complex) daughter radiations from Fm^{254}	multiple n-capt from U^{238}, Pu^{239}, Cm^{244}, Cf^{252}, Es^{253}, etc. (FieP54, ChoG54, HydE64)
Es^{255}	38.3 d (HalvS66) others (GrouCR66, MHarW66, JonM56, ChoG54) $t_{1/2}$ (SF) >170 y (GrouCR66)	☢ β^- 91.5%, α 8.5% (GrouCR66) Δ 84 (MTW)	B chem, genet (ChoG54, JonM56) parent Fm^{255} (ChoG54, JonM56)	α 6.31 daughter radiations from Fm^{255}, [Bk^{251}]	multiple n-capt from U^{238}, Pu^{239}, Cm^{244}, Cf^{252}, Es^{253}, etc. (JonM56, ChoG54, DiaH60, FieP56, GhiA55a, HydE64)
Es^{256}	short (ChoG55)	☢ [β^-] (ChoG55)	F (ChoG55)		E^{255}(n, γ) (ChoG55, HydE64)
$_{100}\mathrm{Fm}^{248}$	0.6 m genet (GhiA58) others (GuseL56)	☢ [α] (GhiA58) Δ 72 (MTW)	B genet, chem (GhiA58) parent Cf^{244} (GhiA58) daughter 102^{252} (MikV66a, GhiA67)		$\mathrm{Pu}^{240}(\mathrm{C}^{12}$, 4n) (GhiA58) $\mathrm{U}^{238}(\mathrm{O}^{16}$, 6n) (GuseL56) (HydE64)
Fm^{249}	≈2.5 m (PerelV59)	☢ α (PerelV59) β^- unstable (cons energy) (MTW) Δ 73.8 (MTW)	B genet, excit, decay charac (PerelV59) parent Cf^{245} (PerelV59)	α 7.9	$\mathrm{U}^{238}(\mathrm{O}^{16}$, 5n) (PerelV59)

Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C^{12}≡0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
$_{100}$Fm^{250}	30 m (AmiS57a, AttH54) others (DoneE62)	☢ α, EC ? (AmiS57a) Δ 74.10 (MTW)	B chem, excit (AttH54, AmiS57a) daughter 102^{254} (GhiA58, DoneE65, MikV66a, GhiA67)	α 7.44	Cf^{249}(α, 3n) (AmiS57a) U^{238}(O^{16}, 4n) (AttH54) (HydE64)
Fm^{251}	7 h (AmiS57a)	☢ EC ≈99%, α ≈1% (AmiS57a) Δ 76 (MTW)	B chem, excit (AmiS57a)	α 6.89 γ [Es X-rays] daughter radiations from Es^{251}	Cf^{249}(α, 2n) (AmiS57a)
Fm^{252}	22.7 h (FrieA56) others (AmiS57a) t$_{1/2}$ (SF) >8 y (FrieA56)	☢ α (FrieA56) β stable (cons energy) (ForB58) Δ 76.84 (MTW)	B chem, genet (FrieA56) chem, excit (AmiS57a) parent Cf^{248} (FrieA56) daughter 102^{256} (DoneE64)	α 7.05	Cf$^{250-252}$(α, xn) (FrieA56) Cf^{249}(α, n) (AmiS57a)
Fm^{253}	3 d (AmiS57) >10 d (FrieA56)	☢ EC 89%, α 11% (AmiS57) Δ 80 (MTW)	B chem (FieP56) chem, genet (AmiS57) parent Es^{253} (AmiS57)	α 6.96 (9%), 6.91 (2%) daughter radiations from Es^{253}	Cf^{252}(α, 3n) (FrieA56, AmiS57)
Fm^{254}	3.24 h (JonM56) others (FieP54, StuM54, ChoG54, HarvB54) t$_{1/2}$ (SF): 246 d (JonM56) 220 d (FieP54) 200 d (ChoG54)	☢ α 99+%, SF 0.055% (JonM56) β stable (cons energy) (ForB58) Δ 80.93 (MTW)	A chem, genet (HarvB54, ChoG54, FieP54, StuM54) daughter Es^{254m} (ChoG54, FieP54) not daughter Es^{254}, lim 3 x 10^{-4}% (MHarW66) parent Cf^{250} (PhiL63)	α 7.20 (82%), 7.16 (17%) γ Cf L X-rays e$^-$ 0.019, 0.036	daughter Es^{254m} (StuM54a, ChoG54, HydE64)
Fm^{255}	20.1 h (AsaF64) others (JonM56, ChoG54) t$_{1/2}$ (SF): 1 x 10^{4} y (PhiL63) others (HydE57)	☢ α (ChoG54) β stable (cons energy) (ForB58) Δ 83.82 (MTW)	B chem, genet (ChoG54) daughter Es^{255} (ChoG54, JonM56) daughter Md^{255} (PhiL58)	α 7.03 (93%) γ Cf L X-rays, 0.059 (0.9%, doublet), 0.081 (1.1%, doublet) e$^-$ 0.032, 0.05-0.07	daughter Es^{255} (ChoG54, JonM56, HydE64)
Fm^{256}	2.7 h (PhiL58, SikT65) others (ChoG55)	☢ SF 97%, α 3% (SikT65) β stable (cons energy) (ForB58) Δ 85.44 (MTW)	B chem, decay charac (ChoG55) daughter Md^{256} (PhiL58)	SF fission fragments, neutrons, γ rays, electrons, daughter radiations α 6.86	Es^{255}(n, γ)[Es^{256}](β$^-$) (ChoG55, HydE64) daughter Md^{256} (PhiL58, SikT65)
Fm^{257}	80 d (SikT65) 79 d (HulE64) 94 d (GrouCR66) others (AsaF66b) t$_{1/2}$ (SF) 100 y (HulE64) 94 y (AsaF66b) others (GrouCR66)	☢ α (HulE64) Δ 88.6 (MTW)	B chem, [genet], excit [parent Cf^{253}], not parent Cf^{254} (HulE64) ancestor Es^{253}, daughter Md^{257} (SikT65)	α 6.53 (94%) γ Cf X-rays, 0.180 (8%), 0.242 (10%) e$^-$ 0.037, 0.045, 0.055, 0.106 daughter radiations from Cf^{253}, Es^{253}	multiple n-capt from Pu^{242}, Am^{243}, Cm^{244}, etc. (HulE64, AsaF66b)
Fm$^{258?}$	≈11 d (GatR63) ≤2 h (GrouCR66)	☢ SF (GatR63)	G chem, decay charac (GatR63) activity not observed (GrouCR66)		multiple n-capt from Cm^{244} (GatR63)
$_{101}$Md^{255}	0.6 h (SikT65) ≈0.5 h (PhiL58)	☢ EC 90%, α 10% (SikT65) Δ 84.4 (MTW)	B chem, genet (PhiL58) parent Fm^{255} (PhiL58)	α 7.34 daughter radiations from Fm^{255}	Es^{253}(α, 2n) (PhiL58) B^{11}, C^{12}, C^{13} on Cf^{252} (SikT65)
Md^{256}	1.5 h (PhiL58, SikT65) others (GhiA55)	☢ EC 97%, α 3% (SikT65) Δ 86.9 (MTW)	B chem (GhiA55) chem, genet (PhiL58) parent Fm^{256} (PhiL58)	α 7.18 daughter radiations from Fm^{256}	Es^{253}(α, n) (GhiA55) B^{11}, C^{12}, C^{13} on Cf^{252} (SikT65)
Md^{257}	3 h (SikT65)	☢ EC ≈92%, α ≈8%, no SF, lim 10% (SikT65) Δ 89 (MTW)	D chem, excit, decay charac (SikT65) parent Fm^{257} (SikT65)	α 7.25 ?, 7.08	B^{11}, C^{12}, C^{13} on Cf^{252} (SikT65)
102^{251}	0.8 s (GhiA67)	☢ α (GhiA67)	E excit, decay charac, cross bomb (GhiA67)	α 8.68 ? (20%), 8.58 (80%)	Cm^{244}(C^{12}, 5n) (GhiA67)
102^{252}	2.1 s (GhiA67) 5 s (MikV66a) 3 s (GhiA58, GhiA59)	☢ α ≈70%, SF ≈ 30% (GhiA59) α (MikV66a) Δ 83 (LHP, MTW)	C excit, decay charac (GhiA59) excit, genet, cross bomb, decay charac (MikV66a, GhiA67) parent Fm^{248} (MikV66a, GhiA67) formerly assigned to 102^{254} (GhiA58, GhiA59)	α 8.41	Cm^{244}(C^{12}, 4n) (GhiA67, GhiA59) Cm^{244}(C^{13}, 5n) (GhiA67) Pu^{239}(O^{18}, 5n) (MikV66a)

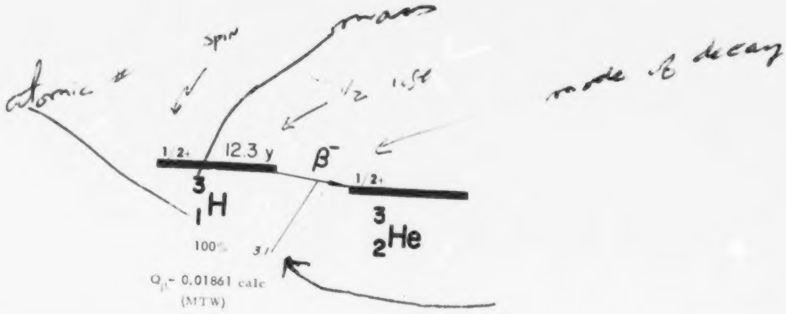
Isotope Z A	Half-life	Type of decay (☢); % abundance; Mass excess (Δ≡M−A), MeV (C 0); Thermal neutron cross section (σ), barns	Class; Identification; Genetic relationships	Major radiations: approximate energies (MeV) and intensities	Principal means of production
102^{253}	95 s (MikV66a) 100 s (GhiA67)	☢ α (MikV66a, GhiA67) Δ 84 (LHP, MTW)	C excit, cross bomb, genet (MikV66a) excit, cross bomb, genet (GhiA67) parent Fm^{249} (MikV66a, GhiA67)	α 8.02	$Cm^{244}(C^{13}, 4n)$, $Cm^{246}(C^{12}, 5n)$ (GhiA67) $Pu^{242}(O^{16}, 5n)$, $Pu^{239}(O^{18}, 4n)$ (MikV66a)
102^{254}	55 s (GhiA67) 50 s (DubG66) 75 s (MikV66a) others (DoneE65, ZagB65)	☢ α (ZagB65, GhiA67, MikV66a) no SF, lim 0.06% (FleG66) Δ 84.8 (LHP, MTW)	C genet (GhiA58, GhiA59) genet, excit (DoneE65) excit, decay charac, cross bomb (MikV66a, GhiA67) parent Fm^{250} (GhiA58, GhiA59, DoneE65, MikV66a, GhiA67)	α 8.10	$Cm^{246}(C^{12}, 4n)$ (GhiA67, GhiA58, GhiA59) $Cm^{246}(C^{13}, 5n)$, $Cm^{244}(C^{13}, 3n)$ GhiA67) $Pu^{242}(O^{16}, 4n)$ (MikV66a) $Am^{243}(N^{15}, 4n)$ (DoneE65, ZagB65, MikV66) $U^{238}(Ne^{22}, 6n)$ (DoneE65)
102^{255}	180 s (DubG66, GhiA67) 2 m (AkaGN66)	☢ α (AkaGN66, DubG66, GhiA67) Δ 87 (LHP, MTW)	C excit, cross bomb, decay charac (AkaGN66) excit, cross bomb, decay charac (DubG66, GhiA67)	α 8.11	$Cm^{246}(C^{13}, 4n)$, $Cm^{248}(C^{12}, 5n)$ (GhiA67) $Pu^{242}(O^{18}, 5n)$ (DubG66) $U^{238}(Ne^{22}, 5n)$ (AkaGN66, DubG66)
102^{256}	2.7 s (GhiA67) 6 s (AkaGN66) 9 s (DubG66) 8 s (KuzV65, DoneE64)	☢ α (DoneE64, AkaGN66, GhiA67) SF 0.5% (KuzV65) Δ 87.83 (LHP, MTW)	C genet, excit (DoneE64) excit, cross bomb, decay charac (DubG66, GhiA67) chem (?) (ChubY66) parent Fm^{252} (DoneE64)	α 8.43	$Cm^{248}(C^{12}, 4n)$, $Cm^{248}(C^{13}, 5n)$, $Cm^{246}(C^{13}, 3n)$ (GhiA67) $Pu^{242}(O^{18}, 4n)$ (KuzV65) $U^{238}(Ne^{22}, 4n)$ (DoneE64, AkaGN66)
102^{257}	20 s (GhiA67)	☢ α (GhiA67) Δ 90 (LHP, MTW)	E excit, cross bomb, decay charac (GhiA61, GhiA67)	α 8.27 (50%), 8.23 ? (50%)	$Cm^{248}(C^{13}, 4n)$, $Cm^{248}(C^{12}, 3n)$ (GhiA67) B^{10}, B^{11} on $Cf^{250-252}$ (GhiA61)
$_{103}Lw^{256}$	≈45 s (DubG66)	☢ α, EC (?) (DubG66)	F excit (DubG66)		$Am^{243}(O^{18}, 5n)$ (DubG66)
$_{103}Lw^{258, 259}$	8 s (GhiA61)	☢ α (GhiA61)	E cross bomb, excit, decay charac (GhiA61, GhiA67a) formerly assigned to Lw^{257} (GhiA61)	α 8.6	B^{10}, B^{11} on $Cf^{250-252}$ (GhiA61)
104^{260}	0.3 s (FleG64)	☢ SF (FleG64) no α, lim 50% (DruV66)	E excit, cross bomb (FleG64) chem (?) (ZvaI66)		$Pu^{242}(Ne^{22}, 4n)$ (FleG64)

Table II

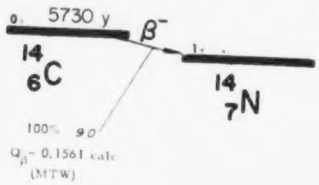
Detailed nuclear level properties

Spin — moments — alpha, beta, and gamma radiation data (energies, intensities, internal conversion coefficients, spectroscopic methods, angular distributions) — decay schemes

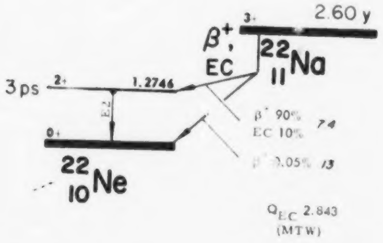
See also
Lederer, Hollander
and Perlman,
Table of Isotopes,
Wiley, 1967.


atomic #
spin
mass
1/2 life
mode of decay
1/2+
12.3 y
β⁻
1/2+
³₁H
³₂He
100%
31
Q_β- 0.01861 calc
(MTW)

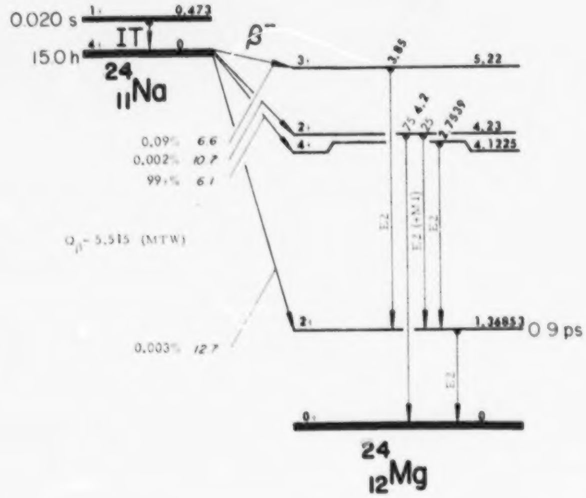
^{3}H (12.3 y):
- I: **1/2** atomic spect; μ: +**2.97885** NMR (LindgI64)
- β⁻: **0.0186** mag spect (PortF59)
  others (LangeL52, CurrS49, HamiD53a, HannG49)


0+
5730 y
β⁻
1+
¹⁴₆C
¹⁴₇N
100%
90
Q_β- 0.1561 calc
(MTW)

^{14}C (5730 y):
- I: **0** atomic spect, microwave (LindgI64)
- β⁻: **0.155** mag spect (FelL49a, WarsS50, ForII54); ion ch (AngJ49)
  0.156 (CookCS48d); **0.154** (LevyP47); **0.159** (PohA55); mag spect
  others (MolA54)
- γ: no conv, mag spect conv (LevyP47); no γ (RubeS41)


3+
2.60 y
β⁺, EC
²²₁₁Na
3ps
2+
1.2746
γ1
0+
²²₁₀Ne
β⁺ 90%
EC 10%
74
β⁺ 0.05%
13
Q_EC 2.843
(MTW)

^{22}Na (2.60 y):
- I: **3**, μ: +**1.746** atomic beam (LindgI64)
- β⁺: β_2 **0.545** (DaniH58a); **0.543** (HamiJ58a); **0.542** (MackP50a); **0.540** (WonC54); mag spect
  β_1 **1.83** († 0.06), β_2 **0.540** († 100) mag spect (WriB53)
  others (GooW46, MorgK49, LeuH61, BranW64a, CharP65)
- γ: γ_1 **1.2746** semicond spect (RobiR65)
  γ_1 (e/γ 6.7×10^{-6}) (NakY63, LeamR54)
  others (MarlK65, SinP59, AlbuD49, AjzF55, GooW46)
- βγ(θ): (GrabZ65, DaniH60a, SubB61b, StevD51, MullH65)
- βγpolariz(θ): (StefR59, BloS62, AppH59, BhaS65, SchoH57)


0.020 s
1+
0.473
IT
4+
0
15.0 h
$^{24}_{11}$Na
β⁻
3+
3.85
5.22
75 4.2
25
2.7539
2+
4.23
4+
4.1225
0.09% 6.6
0.002% 10.7
99+% 6.1
Q_{β^-} = 5.515 (MTW)
E2
E2 (+M1)
E2
2+
1.36853
0.9 ps
0.003% 12.7
E2
0+
0
$^{24}_{12}$Mg

^{24m}Na (0.020 s):

β^-: **6** scint spect (DroB56)

γ with IT: **0.472** scint spect (DroB56, SchaA61)
others (GlagV61, AlexKF60, GlagV59, AlexKF63)

---

^{24}Na (15.0 h):

I: **4**, μ: **+1.69** atomic beam (LindgI64)

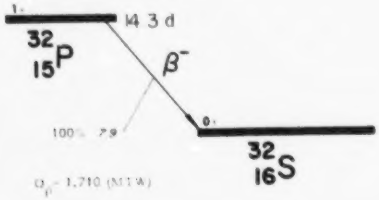
β^-: β_2 **1.389** (DepP61, DepP61a, DaniH58a); **1.394** (PortF57, BeeH65);
1.390 (SiegK46b, SiegK47); mag spect
β_1 **4.17** (0.003%), no **5.5** β^-, mag spect (TurJ51)
others (LawJL39, DHaaE55a, GranP50a)

γ: γ_1 **1.36853**, γ_2 **2.7539** mag spect (MarG65)
γ_3 **3.85** (0.09%), γ_4 **4.23** (0.0015%) mag spect (ArtaK60)
γ_1 (I_γ100, γ_2 (I_γ102) mag spect (DzhB56f)
γ_2 (e/γ 3×10^{-6}) (SiegK50)
γ_1 (e^+/γ 6×10^{-5}), γ_2 (e^+/γ 7.1×10^{-4}) pair spect conv (BloS52)
γ_1 (e^+/γ 3×10^{-5}), γ_2 (e^+/γ 8×10^{-4}) pair spect conv (SiegK52)
γ_1 (e^+/γ 4×10^{-5}), γ_2 (e^+/γ 7×10^{-4}) $\gamma\gamma^\pm\gamma^\pm$ coinc (SpriE65a)
others (HedA52, SiegK46b, MonaJ62a, GooP63, GustL58, KinB53, KnoJ59, WolfsJ50, RobJ49, ElliL43, BegL51, TurJ51)

$\gamma\gamma(\theta)$: (BradE50, CharG50) $\gamma\gamma$polariz(θ): (EstI56)

$\beta\gamma(\theta)$: (GarwR49, AlleR50, BeysJ50a)

$\beta\gamma$polariz(θ): (BloS64, StefR59, BoeF58, MayT59, HaaE63, BloS62)

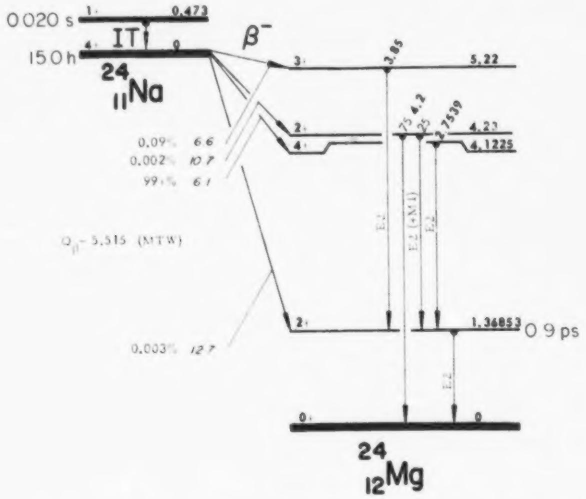

1+
14.3 d
$^{32}_{15}$P
β⁻
100% 7.9
0+
$^{32}_{16}$S
Q_{β^-} = 1.710 (MTW)

^{32}P (14.3 d):

I: **1**, μ: **−0.2523** ESR (LindgI64)

β^-: **1.708** (NieR61); **1.711** (PortF57); **1.712** (ChinC62, PohA56, AttH54, SiegK46b); **1.705** (DaniH58a, FehD61); mag spect
others (JohnO58, ThomRH65, DepP61a, CoroE60, JensE52, ArbE56, DaniH54, LangeL49, WarsS50a, AgnH50, MotH52, SheIR51a, CharP65)

γ: no γ, lim 0.01%, scint spect (GooM53)


0.020 s
1+
0.473
IT
4+
0
15.0 h
$^{24}_{11}$Na
β⁻
3+
3.85
5.22
2+
4+
75 4.2
25
2.7539
4.23
4.1225
0.09% 6.6
0.002% 10.7
99+% 6.1
Q_β - 5.515 (MTW)
E2
E2 (+M1)
E2
2+
1.36853
0.9 ps
0.003% 12.7
E2
0+
0
$^{24}_{12}$Mg

^{24m}Na (0.020 s):

β^-: **6** scint spect (DroB56)

γ with IT: **0.472** scint spect (DroB56, SchaA61)
others (GlagV61, AlexKF60, GlagV59, AlexKF63)

^{24}Na (15.0 h):

I: **4**, μ: +**1.69** atomic beam (LindgI64)

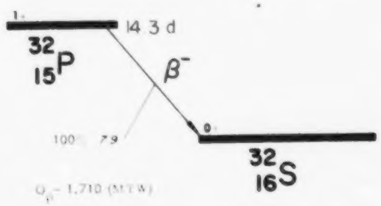
β^-: β_2 **1.389** (DepP61, DepP61a, DaniH58a); **1.394** (PortF57, BeeH65);
1.390 (SiegK46b, SiegK47); mag spect
β_1 **4.17** (0.003%), no **5.5** β^-, mag spect (TurJ51)
others (LawJL39, DHaaE55a, GranP50a)

γ: γ_1 **1.36853**, γ_2 **2.7539** mag spect (MarG65)
γ_3 **3.85** (0.09%), γ_4 **4.23** (0.0015%) mag spect (ArtaK60)
γ_1 (I_γ100, γ_2 (I_γ102) mag spect (DasB56f)
γ_2 (e/γ 3×10^{-6}) (SiegK50b)
γ_1 ($e^\pm/\gamma$ 6×10^{-5}), γ_2 ($e^\pm/\gamma$ 7.1×10^{-4}) pair spect conv (BloS52)
γ_1 ($e^\pm/\gamma$ 3×10^{-5}), γ_2 ($e^\pm/\gamma$ 8×10^{-4}) pair spect conv (SiegK52)
γ_1 ($e^\pm/\gamma$ 4×10^{-5}), γ_2 ($e^\pm/\gamma$ 7×10^{-4}) $\gamma\gamma^\pm\gamma^\pm$ coinc (SpriE65a)
others (HedA52, SiegK46b, MonaJ62a, GouP63, GastL58, KinB53, KnoJ59, WolfsJ50, RobiJ49, ElliL43, BegL51, TurJ51)

$\gamma\gamma(\theta)$: (BradE50, CharG50) $\gamma\gamma$polariz(θ): (EstI56)

$\beta\gamma(\theta)$: (GarwR49, AlleR50, BeyJ50a)

$\beta\gamma$polariz(θ): (BloS64, StefR59, BoeF58, MayT59, HaaE63, BloS62)

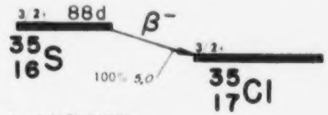

1+
14.3 d
$^{32}_{15}$P
β⁻
0+
100% 7.9
Q_β - 1.710 (MTW)
$^{32}_{16}$S

^{32}P (14.3 d):

I: **1**, μ: −**0.2523** (LindgI64)

β^-: **1.708** (NiR61); **1.711** (PortF57); **1.712** (ChinC62, PohA56, AttH54, SiegK46b); **1.705** (DaniH58a, FehD61); mag spect
others (JohnO53, ThomRH65, DepP61a, CoroE60, JensE52, ArbE56, DaniH54, LangeL49, WarsS50a, AgnH50, MotH52, SheIR51a, CharP65)

γ: no γ, lim 0.01%, scint spect (GooM53)


3/2+
88d
$^{35}_{16}$S
β^-
100% 5.0
3/2+
$^{35}_{17}$Cl

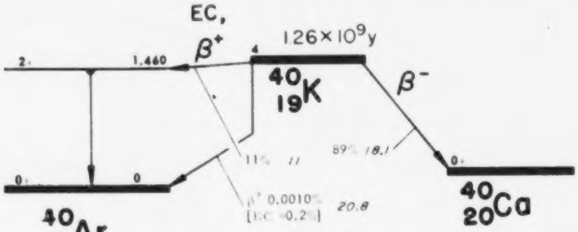
Q_{β^-} 0.1674 (MTW)

^{35}S (88 d):

I: **3/2**, μ: ±**1.00**, q: +**0.05** microwave (LindgI64)

β^-: **0.1674** (ConnR57); **0.1670** (LangeL50a); mag spect
others (HellR51, FeuL54, GrossL50, CocA49, AlbeR48)

β^- polariz: (LangeH58)


EC,
β^+
1.26×10^9y
4
$^{40}_{19}$K
β^-
2+
1.460
0+
0
$^{40}_{18}$Ar
11% 11
β^+ 0.0010%
[EC ≈0.2%]
20.8
89% 18.1
0+
$^{40}_{20}$Ca

Q_{β^-} 1.314 calc
Q_{EC} 1.505 calc
(MTW)

^{40}K (1.26×10^9 y):

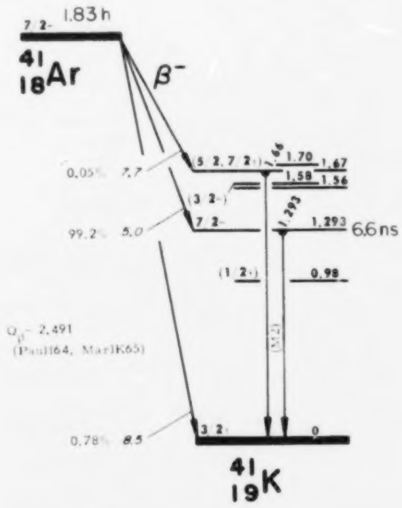
I: **4** atomic beam; μ: **−1.2981** atomic beam; **1.2978** NMR; q: **−0.09** opt double res (LindgI64)

β^-: **1.33** (FeIL52); **1.36** (AlbuD50a); mag spect
1.32 (KonoS55); **1.35** (KellWH59); **1.36** (BellP50a) scint spect
others (MarsJH53, GooML51b, DzB46)

β^+: **0.49** (β^+/β^- 1.1×10^{-5}) $\beta^+\gamma^{\pm}\gamma^{\pm}$ coinc (EngeD62)

γ with EC: γ_1 **1.460** scint spect (RobiB64)
γ_1 **1.46** (γ/β^- 0.123) scint spect, ion ch (MNaIA56)
others (BellP50b, GooML51, HofsR50, PriR50)

EC(K)/β^- 0.14 ion ch (SawG50)

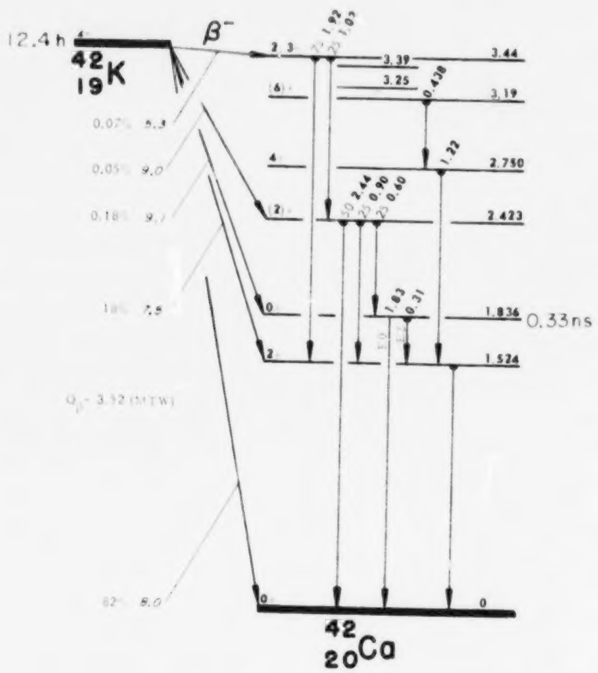

7/2-
1.83h
$^{41}_{18}$Ar
β^-
0.05% 7.7
99.2% 5.0
(5/2, 7/2+)
1.66
1.70
1.67
1.58
1.56
(3/2-)
1.293
7/2-
1.293
6.6ns
(1/2+)
0.98
Q_{β^-} 2.491
(PaulI64, MarlK65)
(M2)
0.78% 8.5
3/2+
0
$^{41}_{19}$K

^{41}Ar (1.83 h):

β^-: β_2 **1.198** mag spect (PaulI64)
β_1 **2.49** (0.78%), β_2 **1.20** (99+%) mag spect (KartG61)
others (SchwaA56, BrowH50)

γ: γ_1 **1.293** scint spect (MarlK65)
γ_1 **1.290** (e/γ 7×10^{-5}) mag spect conv (KartG61)
γ_1 (I_γ100), γ_2 **1.66** (I_γ0.05) scint spect, γγ coinc (PraW65)
γ_1 ($I_{\gamma\gamma}/I_\gamma$ $<6 \times 10^{-5}$) γγ coinc (AlvT62)
others (SchwaA56, KluJ55)

βγ(θ): (BocF60a) βγpolariz(θ): (BloS62, ChabM62, MayT60, BloS60)


12.4 h
4-
$^{42}_{19}K$
β^-
0.07% 8.3
0.05% 9.0
0.18% 9.1
18% 7.5
82% 8.0
Q_{β^-} 3.52 (MTW)
2,3-
(6)+
4+
(2)+
0+
2+
0+
3.44
3.39
3.25
3.19
2.750
2.423
1.836
1.524
0
0.33ns
1.92
1.02
0.438
1.22
2.44
0.90
0.60
1.83
0.31
E0
$^{42}_{20}Ca$

^{42}K (12.4 h):

I: **2** μ: **−1.141** atomic beam (LindgI64)

β^-: β_1 **3.52** mag spect (DaniH64a)

β_1 **3.55**, β_2 **1.99**, **0.5** ? (≈1%) (PohA56)

β_1 **3.56** (82%), β_2 **1.97** (18%) mag spect, βγ coinc (KoerL54a)

others (SiegK47c, CharP65)

γ: γ_5 **1.524** scint spect (MarlK64)

γ_5 (γ 18%) βγ coinc (PersB62)

γ_1 **0.31** (I_γ1.1), γ_2 **0.60** (I_γ0.1), γ_3 **0.90** (I_γ0.1), γ_4 **1.02** (I_γ0.1), γ_5 **1.52** (I_γ100), γ_7 **1.92** (I_γ0.3), γ_8 **2.44** (I_γ0.2) scint spect, γγ coinc (MCulJ61)

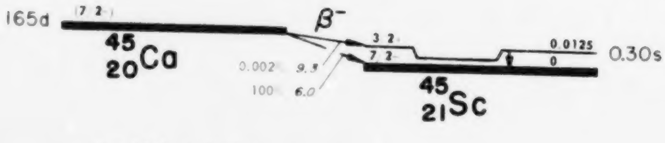
γ_1 **0.301** (I_e-10), γ_6 **1.83** (I_e-10, e^+/e^- 9) mag spect conv (BencN61)

others (PohA56, SiegK47c, MackJ59, KahB53, EmeE55a, CapU54, GatC60)

γγ(θ): (AspI59, AspI59a, MoriH59a)

βγ(θ): (SteB61, StevD51a, BeyeJ50a, HamiD53)

βγpolariz(θ): (DaniH61, DsaiP64, HamiD53)

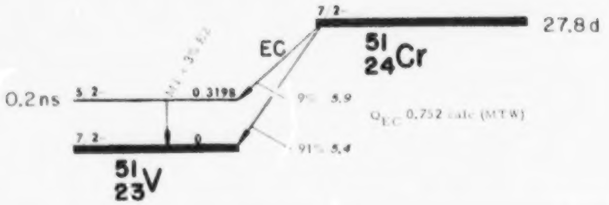

165d
(7/2-)
$^{45}_{20}Ca$
β^-
0.002% 9.5
100% 6.0
3/2-
7/2-
0.0125
0
0.30s
$^{45}_{21}Sc$

Q_{β^-} 0.252 calc (MTW)

^{45}Ca (165 d):

β^-: **0.254** mag spect (MackP50a)
0.255 scint spect (KetB50b)
0.261 mag spect (MargL53a)
0.258 mag spect (FreeM65)

γ: **0.0125** (K 1.4 × 10^{-5}%) mag spect conv (FreeM65)


7/2−
27.8 d
EC
$^{51}_{24}$Cr
M1 + 3% E2
0.2 ns
5/2−
0.3198
9% 5.9
Q_{EC} 0.752 calc (MTW)
7/2−
0
91% 5.4
$^{51}_{23}$V

^{51}Cr (27.8 d):

I: **7/2** atomic beam (LindgI64)

γ: γ_1 **0.3198** semicond spect (RobiR65)

γ_1 **0.325** (γ 9%), **0.320** (γ 0.001%), **0.65** (γ 0.0005%) scint spect, $\gamma\gamma$ coinc (OfeS57b)

γ_1 **0.325** (e_K/γ 0.0015) mag spect, mag spect conv (OFriZ56)

γ_1 (γ 21%, e_K/γ 0.0015) scint spect, mag spect conv (MacD52)

γ_1 (γ 9.8%, e_K/γ 0.0016) scint spect, mag spect conv (BunkM55)

γ_1 (e/γ 0.0031) mag spect, mag spect conv (EstI55)

γ_1 (γ 8%) scint spect (VKooJ56); scint spect, Xγ coinc (LyoW52)

γ_1 (γ 9.8%), **0.624** (γ 0.026%) scint spect (BisA55c)

0.15 (γ 0.0008%), **0.32** (γ 0.0010%), γ_1 **0.323**, **0.47** (γ 0.0003%), **0.63** ? (very weak) scint spect, $\gamma\gamma$ coinc, $\gamma\gamma$ sum coinc (MathG63)

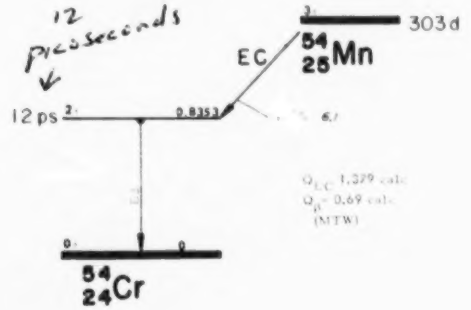
others (KerB49, BradH45b, NusR53c, KuriF48, CurrS52, MillL46, OhiK65)

EC(L)/EC(K) 0.103 (FasU62, HeuW64)
others (KonsA61)

EC decay to **0.320** level of ^{51}V: EC(L)/EC(K) 0.104 (HeuW64)

nucl align: (KapM61)

0.77 level of ^{51}Cr: $t_{1/2}$ 1.1 × 10^{-8} s delay coinc (BaueR63)


12 picoseconds
3+
303 d
EC
$^{54}_{25}$Mn
12 ps
2+
0.8353
6.1
E2
Q_{EC} 1.379 calc
Q_{β^-} 0.69 calc
(MTW)
0+
0
$^{54}_{24}$Cr

^{54}Mn (303 d):

I: **3**, μ: +**3.3** nucl align (LindgI64)

γ: γ_1 **0.8355** (ParsD65); **0.8350** (RobiR65); semicond spect

γ_1 (e/γ 0.00025) mag spect, mag spect conv (HamiJ66)

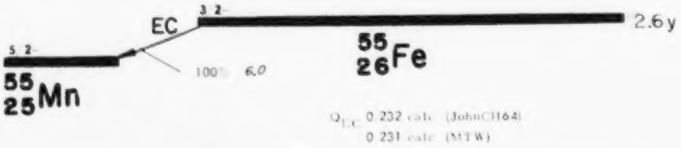
γ_1 **0.838** (K/L+M+... 8) mag spect conv (KatoT58)

no other γ, lim 0.1% (KatoT58)
others (WilsRR63, RaoG63b, MacD54a, DeuM44)

nucl align: (BaueR60b, GracM54)

EC(L)/EC(K): 0.106 ion ch (ManduC63)
0.10 ion ch (MolR63)

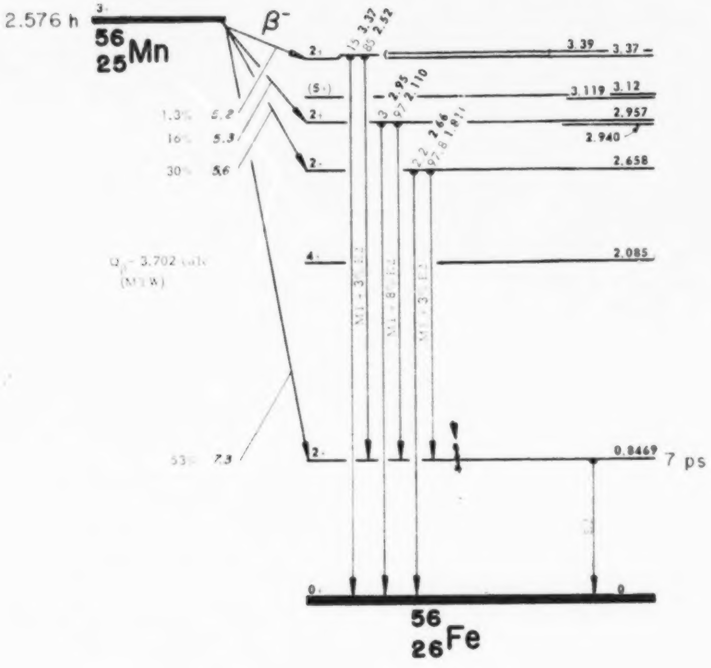
EC(L+M+...)/EC(K): 1.1 ion ch (KraP62)


3/2−
EC
2.6 y
5/2−
100% 6.0
$^{55}_{26}$Fe
$^{55}_{25}$Mn
Q_{EC} 0.232 calc (JohnCH64)
0.231 calc (MTW)

^{55}Fe (2.6 y):

internal bremsstrahlung endpoint: **0.23** (EmmW54a)
0.22 (MadaL54)
0.21 (MicA53, BellP52, MacD51a, MacD51)
others (BolP53)

EC(L)/EC(K): 0.106 ion ch (ManduC62, MolR63)
0.108 ion ch (ScoJ59)


2.576 h
3+
56
25Mn
β⁻
1.3% 5.2
16% 5.3
30% 5.6
53% 7.3
Qβ- 3.702 calc
(MTW)
2+
(5+)
2+
2-
4+
2-
0+
15 3.37
85 2.52
2.95
2.110
3
97
2.66
1.811
2.2
97.8
M1 + 3% E2
M1 + 8% E2
M1 + 3% E2
3.39
3.37
3.119
3.12
2.957
2.940
2.658
2.085
0.8469
7 ps
0
56
26Fe

^{56}Mn (2.576 h):

I: **3** μ: +**3.2403** atomic beam (LindgI64)

β^-: β_1 **2.84** (47%), β_2 **1.03** (34%), β_3 **0.72** (18%), β_4 **0.30** (1%) mag spect (HowD62a)

β_1 **2.86** (60%), β_2 **1.05** (25%), β_3 **0.75** (15%) mag spect (ElliL43a)

β_1 **2.81** (50%), β_2 **1.04** (30%), β_3 **0.65** (20%) mag spect (SiegK46a)

others (TownA41, VasiSS61, CharP65)

γ: γ_1 **0.8468**, γ_2 **1.811**, γ_3 **2.110** cryst spect (ReidyJ65)

γ_1 **0.845** (I_γ100), γ_2 **1.81** (I_γ30), γ_3 **2.12** (I_γ15.3), γ_4 **2.52** (I_γ1.2), γ_5 **2.65** (I_γ0.7), γ_6 **2.95** (I_γ0.4), γ_7 **3.39** (I_γ0.21) scint spect (CookCS58)

γ_2 ($e^\pm/\gamma$ 0.0006), γ_3 ($e^\pm/\gamma$ 0.0005) mag spect conv (SlaH52)

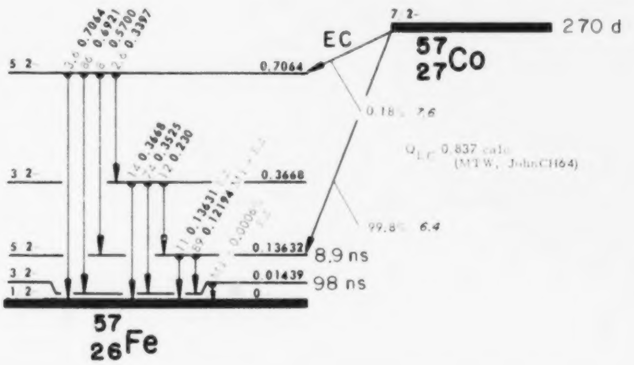
others (DagP59, GroshL57a, KieP59, BieJ64a, LeviN58, ElliL43a, SiegK46a, MunM55, KikS42, GermE53, MetF53c)

γγ(θ): (DagP59, LeviN58, MetF53c, MaliS59)

βγ(θ), βγpolariz(θ): (LobV62) nucl align: (DagP59, BaueR60a)

0.026 level of ^{56}Mn: $t_{1/2}$ 1.14 × 10^{-8} s delay coinc (DToiS61)
1.04 × 10^{-8} s delay coinc (BoniM64)
others (DAngN60)

0.109 level of ^{56}Mn: $t_{1/2}$ 5.1 × 10^{-9} s delay coinc (DToiS61, BoniM64)
others (DAngN60)


7/2-
270 d
EC
$^{57}_{27}$Co
5/2-
3/2-
5/2-
3/2-
1/2-
0.7064
0.6921
0.5700
0.3397
0.3668
0.3525
0.230
0.13631
0.12194
0.0006
0.7064
0.3668
0.13632
0.01439
0
8.9 ns
98 ns
0.18% 7.6
Q_{EC} 0.837 calc
(MTW, JohnCH64)
99.8% 6.4
$^{57}_{26}$Fe

^{57}Co (270 d):

I: **7/2**, μ: **+4.85** ESR (LindgI64)

γ: γ_1 **0.01439** mag spect conv (MehW63)

γ_1 **0.01437** (I_K43, K/L 8.9), γ_2 **0.12194** (I_K1.00, K/L+M+... 6.7), γ_3 **0.13631** (I_K0.85, K/L+M+... 8.2) mag spect conv (BellJ57a, BellJ56, BellJ55, BellJ57)

γ_1 (γ 8.4%), γ_2 (γ 85%), γ_3 (γ 11%), γ_4 **0.231** (γ 0.0005%), γ_5 **0.3397** (γ 0.0048%), γ_6 **0.3524** (γ 0.0037%), γ_7 **0.3667** (γ 0.0007%), γ_8 **0.5703** (γ 0.014%), γ_9 **0.6921** (γ 0.16%), γ_{10} **0.7068** (γ 0.0067%) semicond spect (SproG65)

γ_1 (e/γ 9.0), γ_2, γ_3 ($I_\gamma(\gamma_2)/I_\gamma(\gamma_3)$ 8.0), γ_4 **0.230** (γ 0.0005%), γ_5 **0.3397** (γ 0.0042%), γ_6 **0.3525** (γ 0.0032%), γ_7 **0.3668** (γ 0.0006%), γ_8 **0.5700** (γ 0.013%), γ_9 **0.6921** (γ 0.14%), γ_{10} **0.7064** (γ 0.0057%) semicond spect, γγ coinc (KisO65a)

γ_2 (I_γ87), γ_3 (I_γ10.5), γ_4 **0.230** (I_γ≈0.0004), γ_5 **0.340** (I_γ0.0025), γ_6 **0.353** (I_γ0.0017), γ_7 **0.367** (I_γ0.0006), γ_8 **0.570** (I_γ0.014), γ_9 **0.693** (I_γ0.16), γ_{10} **0.707** (I_γ0.0048) semicond spect (MathJ65)

γ_1 (e/γ 9.0) Mossbauer (NusR65); (e/γ 10) ion ch, scint spect (ThomH63); (e/γ 15) ion ch, scint spect (LernH55); (e_K/γ 8.4, K/L+M+... 9) ion ch, scint spect (MuiA63)

γ_1 **0.01441** (K/L_I/L_{II+III} 110/10/0.9) mag spect conv (EwaG60a)

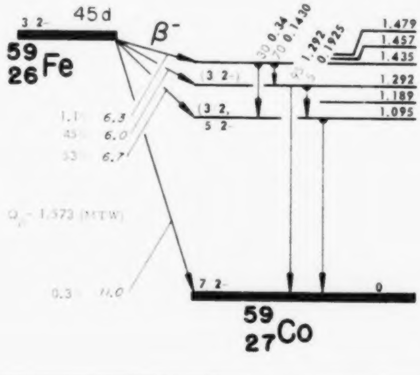
γ_2 (I_γ100, e/γ 0.01), γ_3 (I_γ7, e/γ 0.1) mag spect conv, scint spect (AlbuD54b)

others (ChupE58, CorkJ55, CrasB55, MadaL55, FergJ59, FoN62, GracM56, HillL43a, PleE42, DeuM50)

γγ(θ): (LindqT57b)

EC decay to **0.136** level of ^{57}Fe: EC(L)/EC(K) 0.10 (MolR63)
others (KraP62, MoussA56)

1.49 level of ^{57}Co: $t_{1/2}$ 1.0 × 10^{-9} s delay coinc (NaiT61)
<3 × 10^{-10} s delay coinc (VFabC62)


3/2-
45 d
$^{59}_{26}$Fe
β-
0.34
0.1430
1.292
0.1925
1.479
1.457
1.435
1.292
1.189
1.095
(3/2-)
(3/2,
5/2-
1.1% 6.3
45% 6.0
53% 6.7
Q_{β^-} 1.573 (MTW)
0.3% 11.0
7/2-
0
$^{59}_{27}$Co

^{59}Fe (45 d):

I: **3/2** atomic beam (LindgI64)

β^-: β_1 **1.573** (0.30%), β_2 **0.475** (51%), β_3 **0.273** (48%) mag spect (WorD63)

β_1 **1.56** (0.3%), β_2 **0.462** (54%), β_3 **0.271** (46%) mag spect (MetF52b)

others (BereD60, BrowD52, DeuM42a)

γ: γ_1 **0.1430**, γ_2 **0.1925**, γ_4 **1.095**, γ_5 **1.292** semicond spect (PruS65a)

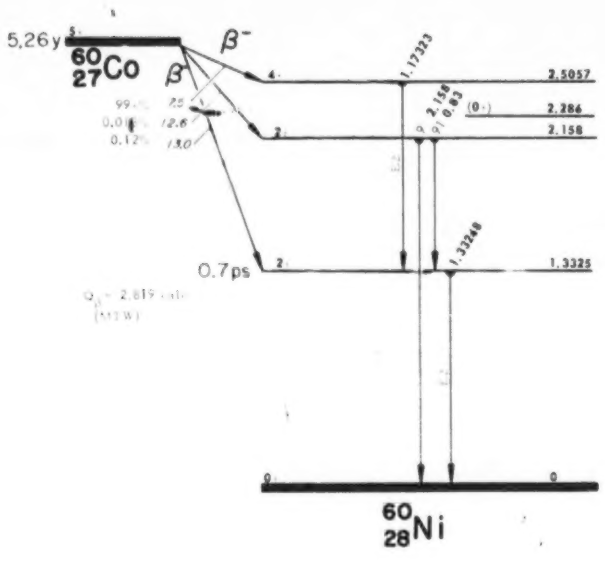
γ_1 **1.145** (γ 0.8%), γ_2 **0.192** (γ 2.5%), γ_3 **0.34** (γ 0.3%), γ_4 **1.10** (γ 56%), γ_5 **1.29** (γ 44%) scint spect, γγ coinc (HeaR60)

γ_1 (γ 0.8%), γ_2 (γ 2.8%), γ_3 (γ 0.7%), γ_4 (γ 56%, e/γ 0.00014), γ_5 (γ 43%, e/γ 0.00011) scint spect, mag spect conv (CollW64a)

others (FergJ59a, WorD63, BereD60, MetF52b, HedA50, DzhB56g, SubB60a, KantM62)

γγ(θ): (HeaR60, SchiffD53, BereD63a) βγ(θ): (FusE60)

βγpolariz(θ): (CollW64a, MannL65, ForH60, MannL62a, KneU65)


5,26 y
5+
60
27Co
β⁻
β⁻
99+%
7.5
0.01%
12.6
0.12%
13.0
4+
2+
2+
1.17323
2.158
0.83
(0+)
2.5057
2.286
2.158
E2
1.33248
0.7ps
1.3325
E2
Qβ⁻ 2.819 calc
(MTW)
0+
0
60
28Ni

^{60}Co (5.26 y):

I: **5**, μ: +**3.75** LNB (LindgI64)

β^-: β_2 **0.319** (KamaK58); **0.309** (BulG54); **0.318** (WagM50); **0.306** (FanC52),
0.314 (KeiG54); mag spect
β_1 **1.48** (0.12%) (CamD61); **1.48** (0.010%) (WolfsJ56); **1.48** (0.15%)
(KeiG54); mag spect
others (DeuM45, BoehF59, YosY53, MilH47)

γ: γ_1 **1.17323**, γ_2 **1.33248** mag spect, mag spect conv (MurG65)
γ_1 (e_K/γ 0.000165) mag spect, mag spect conv (FreyW62)
γ_1 (e_K/γ 0.000173), γ_2 (e_K/γ 0.000129) mag spect conv (WagM50,
WagM50a)
γ_1 (e_K/γ 0.000150, K/L+M+... 9.1), γ_2 (e_K/γ 0.000116, K/L+M+...
9.1) mag spect conv (KamaK58)
γ_1 (e_K/γ 0.000173), γ_2 (e_K/γ 0.000124) mag spect conv (FanC52)
$\gamma_1 + \gamma_2$ ($e^{\pm}/\gamma$ 0.204) e^+e^- coinc (LanghH61a)
γ_3 **2.158** (γ 0.0012%) mag spect (WolfsJ56)
2.5 (≈0.00004%) D-γ-n (MuriH59)
others (AvoM58, LindsG53, HornW49, KlemE53, AeplH52a, ChatS53,
LawJS53, LemH54, WieT54, ColoS55, DahB51, SiegK50a)

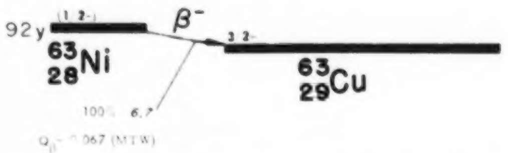
γγ(θ): (GargJ60, BradE50, KluR52, ChatS53, KlemE53, LawJS53, WieT54)

γγpolariz(θ): (MetF50, WillAH50, KloR52)

βγ(θ): (DaniH60a, LobV62b, GarwR49, AllcR50, BeysJ50a, NoveT50,
SluW51)

βγpolariz(θ): (JagP60, BloS62, AppH59, LobV59, SteR59, PagL58,
BhaS65, DebP57, LunA57, SchoH57)

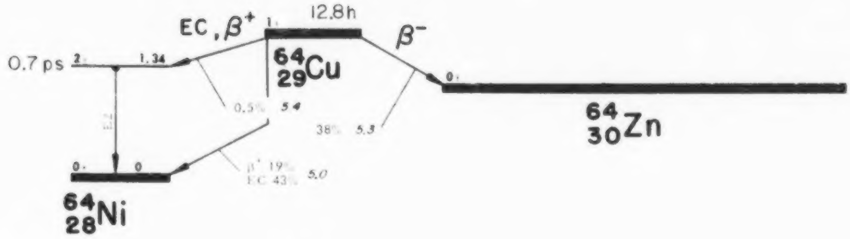
nucl align: (SamB61, LeviM60, DaniJ61, GracM59, KogA58, BisG52,
DaniJ52)


92 y
(1/2-)
63
28Ni
β⁻
3/2-
63
29Cu
100%
6.7
Qβ⁻ 0.067 (MTW)

^{63}Ni (92 y):

β^-: **0.067** ion ch (PrelI57, BrosA51), scint spect (HorrD62)
0.062 electrostatic analyzer (KohY53a)
0.073 abs, ion ch (MEwaJ59)
0.063 ion ch (WilsH49)

γ: no γ (WilsH49, BrosA51)


EC, β^+
1+
12.8h
β^-
0.7 ps
2+
1.34
$^{64}_{29}$Cu
0.5%
5.4
38%
5.3
0+
$^{64}_{30}$Zn
E2
0+
0
β^+ 19%
EC 43%
5.0
$^{64}_{28}$Ni

Q_{β^-} 0.573
Q_{EC} 1.678
(MTW)

^{64}Cu (12.8 h):

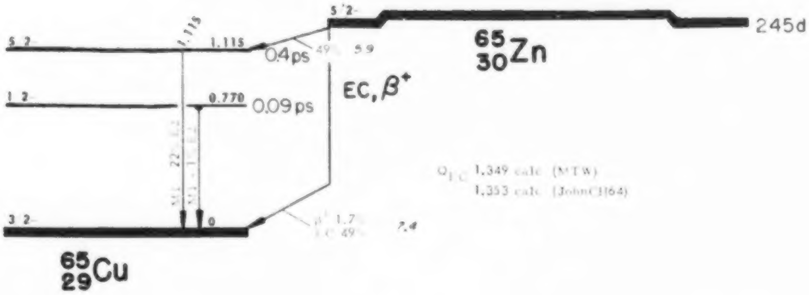
I: **1**, μ: +**0.216** atomic beam (LindgI64)

β^-: **0.571** (CookCS48, OweG49); **0.578** (TylA39); **0.574** (TownA41); mag spect others (BradH46a, BouR49, LangeL49b, SchmW59)

β^+: **0.657** (CookCS48, OweG49); **0.659** (TylA39); **0.649** (TownA41); mag spect others (BradH46a, BouR49, SchmW59, PlaE51)

γ: **1.34** mag spect (KuriF48)
1.32 (γ/β^+ 0.028) scint spect (SchmW59)
1.35 (γ/β^+ 0.025) mag spect (DeuM47)
1.35 (γ/β^+ 0.041) mag spect (AjzF56, DzhB53)
1.34 (e_K/γ 0.00013) mag spect conv (BrowD52)
others (VlaH52, KubH50, MeyW48, MerS51, HubeO49, BouR50)

β^- polariz: (VisM57) $\gamma^{\pm}\gamma^{\pm}(\theta)$: (HannS57)


5/2-
1.115
1.115
0.4ps
49%
5.9
5/2-
245d
$^{65}_{30}$Zn
1/2-
0.770
0.09ps
EC, β^+
22%
M1
M1
3/2-
0
β^+ 1.7%
EC 49%
7.4
$^{65}_{29}$Cu

Q_{EC} 1.349 calc (MTW)
1.353 calc (JohnCH64)

^{65}Zn (245 d):

I: **5/2**, μ: +**0.7692**, q: −**0.024** opt double res (ByrF64)

β^+: **0.325** (MannK49, BashA53b, PerkJ53); **0.327** (SakM53); **0.320** (YuaT53); **0.324** (AviP56); mag spect

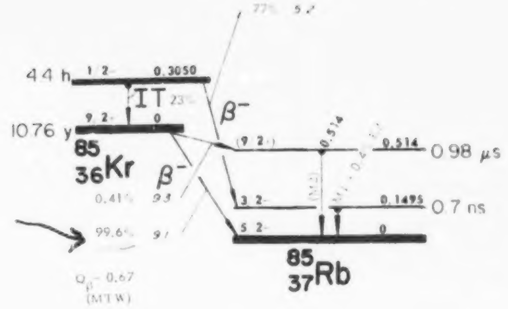
γ: γ_1 **1.1156** semicond spect (RobiR65)
γ_1 (e_K/γ 0.00017) mag spect, mag spect conv (HamiJ66)
γ_1 (e/γ 0.00018) mag spect, mag spect conv (AjzF56, SakM53, BashA53b, BouR53, ShimS62)
γ_1 (49%) (RiceR60b); (51%) (GleG59); (44%) (FurS51); (48%) (SehR54) scint spect, $\gamma\gamma^{\pm}$, γX coinc
others (MarlK65, SinP59, MannK49, HedA50, WagM50a, GooML51, JohaK56, AjzF56, BashA53a, SehR54, PerkJ53, JensE49, StuE54, MacD54, DzhB56d, BouR52, PerrN53, GriG51)

EC to **1.115** level of ^{65}Cu: EC(L)/EC(K) 0.12 (SanAG62)
EC(L+M+...)/EC(K) 0.16 (KraP62)

0.054 level of ^{65}Zn: $t_{1/2}$ 1.65 × 10^{-6} s delay coinc (AugL60)

Isomeric Transition

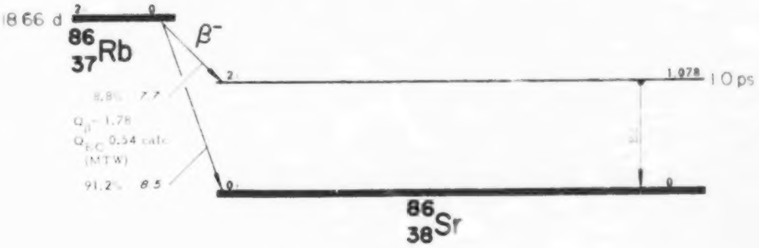
but .4% goes by gamma



77% 9.2
4.4 h
1/2-
0.3050
IT 23%
β^-
9/2+
0
10.76 y
$^{85}_{36}$Kr
β^-
0.41% 9.3
99.6% 9.1
Q_{β^-} 0.67
(MTW)
(9/2+)
0.514
(M2)
0.514
0.98 μs
3/2-
0.1495
0.7 ns
5/2-
0
$^{85}_{37}$Rb

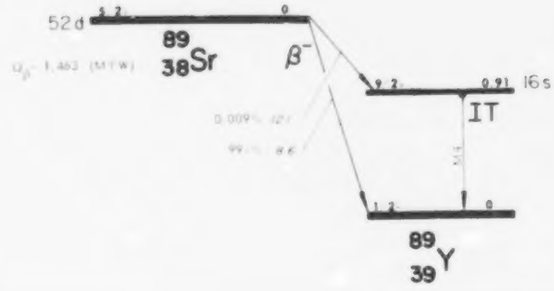
^{85}Kr (10.76 y):
I: **9/2**, μ: **−1.004**, q: **+0.45** atomic spect (LindgI64)
β^-: β_1 **0.67** mag spect (ThuS55, BergI52)
β_1 **0.69** (99.4%), β_2 **0.15** (0.6%) mag spect, $\beta\gamma$ coinc abs (ZeIH50)
γ: γ_1 **0.517** scint spect (ThuS55)
γ_1 (γ 0.41%) scint spect (EasT64)
γ_1 **0.514** (γ 0.38%) scint spect (LyoW61)
others (GeiKW61, NakI60, ZeIH50)

^{85m}Kr (4.4 h):
β^-: **0.82** mag spect (ThuS55)
0.83 mag spect (BergI52, BergI51)
γ: **0.1495** (with β^-, I_γ57, e_K/γ 0.040), **0.3050** (with IT, I_γ10, e_K/γ 0.41, K/L+M+... 6) mag spect conv, scint spect (BergI51, BergI52, BergI54, ThuS55, BergI50a)



18.66 d
2-
0
$^{86}_{37}$Rb
β^-
8.8% 7.7
Q_{β^-} 1.78
Q_{EC} 0.54 calc
(MTW)
91.2% 8.5
2+
1.078
1.0 ps
E2
0+
0
$^{86}_{38}$Sr

^{86}Rb (18.66 d):
I: **2**, μ: **−1.691** atomic beam (LindgI64)
β^-: β_1 **1.78** mag spect (average of MacqP54, LabJ56, ZafD48a, AjzF56, DMitA54, MoreaJ52, MackP51, PohA54, CaiR54, BerlE56, DaniH64a)
β_2 **0.71** mag spect, $\beta\gamma$ coinc (average of MacqP54, CaiR54, PohA54, DMitA54, AjzF56, ZafD48a, MackP51, MueH50, MandeC50, LabJ56, BerlE56, RobiR58a)
others (ThomRH65)
γ: γ_1 **1.077** mag spect (HarpJ63)
γ_1 (γ 8.8%) scint spect, $\beta\gamma$ coinc (BranHW62)
others (PohA54, MueH50, ZafD48a, LyoW54a, EmeE55a, DMitA54, AjzF56, MacqP54, CamP60, MarlK65, GupU65)
$\beta\gamma(\theta)$: (HamiJ61, DeuJ61, MartiB65, SimmP65, AlbeJE63, FiscH60, StevD51, MacqP54)
$\beta\gamma$polariz(θ): (BoeF63a, DaniH61, SimmP65, RogeJ62, DaniH61, BoeF58a, HamiD53, KneU65a)


52d
5/2+
0
89
38Sr
Q_{β^-} 1.463 (MTW)
β⁻
9/2+
0.91
16s
IT
0.009%
99+%
M4
1/2-
0
89
39Y

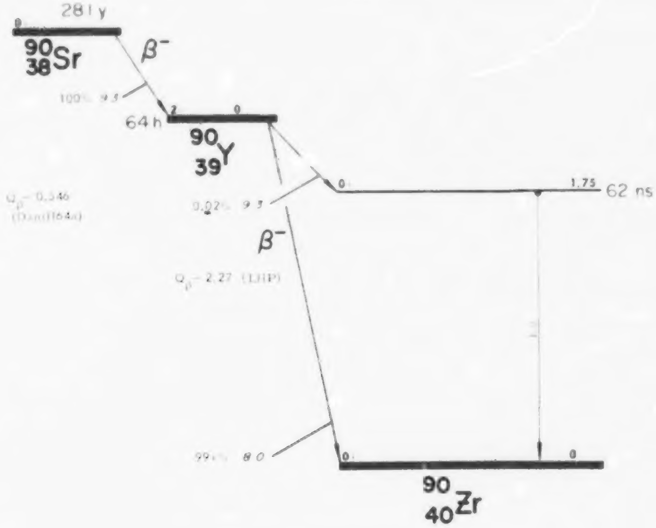
^{89}Sr (52 d):

β⁻: **1.463** (LangeL49), **1.462** (BisA55d); mag spect
others (SlaL49a, RalW47)

γ: no γ (NoveT51, StewD37, StewD39)
0.913 (with ^{89m}Y) (HerreG56, LyuW55b, SatA62)

^{89m}Y (16 s):

γ: γ_1 **0.908** scint spect (VPatD64); **0.913** scint spect (SatA62); mag spect conv (ShoF51); **0.915** scint spect (MonaS61, HamiJ60)
γ_1 (e/γ 0.01) mag spect conv, scint spect (ShuK51, GoldhM51)
γ_1 (K/L+M+... 7) mag spect conv (BendW52)
others (HydE51)


28.1 y
0
90
38Sr
β⁻
100% 9.3
64h
2
0
90
39Y
Q_{β^-} 0.546 (DaniH64a)
0.02% 9.3
0+
1.75
62 ns
β⁻
Q_{β^-} 2.27 (LHP)
E0
99+% 8.0
0+
0
90
40Zr

^{90}Sr (28.1 y):

β⁻: **0.546** mag spect (DaniH64a)
others (BerlE56, NaiT56, LagL50, MeyW48a, BradC49)

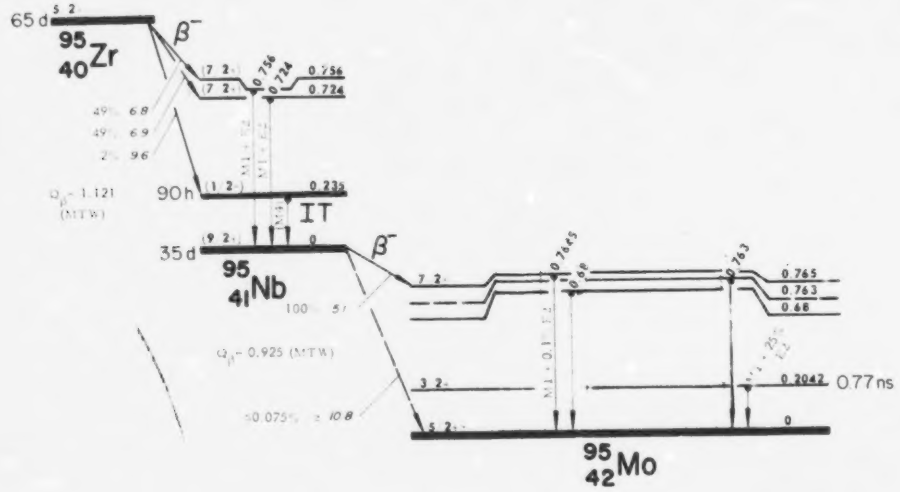
γ: no γ abs (GleL51c)

^{90}Y (64 h):

I: **2**, μ: **−0.163** atomic beam (LindgI64)

β⁻: **2.268** (AndrS64, JohnO58), **2.271** (NicR61), **2.284** (DaniH64a), **2.273** (LangeL64a) mag spect
others (YuaT57b, BerlE56, LangeL49, MajJ52, JohnO55, BradC49, LasL50, NaiT56)

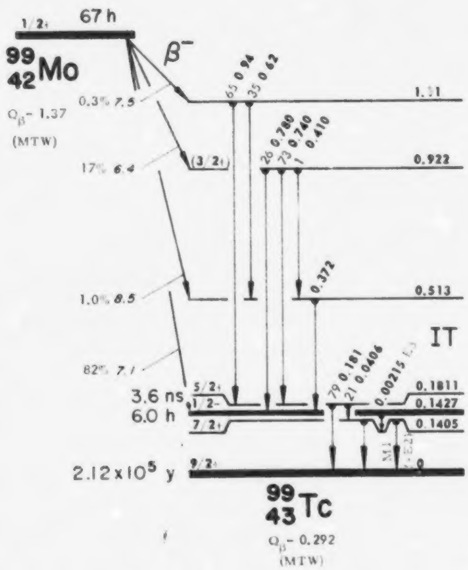
γ: γ_1 **1.734** (e^- 0.016%, e^-/γ > 30, e^+/e^- 3) mag spect conv, scint spect (YuaT56a, YuaT57a)
γ_1 **1.75** (e^- 0.5%, e/γ very large) mag spect conv (JohnO55)
γ_1 ($I_{\gamma\gamma}/I_{e^-}$ <0.0006) mag spect conv (RydH63b)
others (GoroS61a, GoroS61f, LanghH61, AlbuD58, RydH61, DeuM57, GreeJ56)


65 d
5/2+
$^{95}_{40}$Zr
β^-
(7/2+)
(7/2+)
0.756
0.724
0.756
0.724
49% 6.8
49% 6.9
2% 9.6
M1 + E2
M1 + E2
Q_β = 1.121 (MTW)
90 h
(1/2-)
0.235
M4
IT
35 d
(9/2+)
0
$^{95}_{41}$Nb
β^-
100% 5.1
Q_β = 0.925 (MTW)
≈0.075% ≥ 10.8
7/2+
3/2+
5/2+
0.7645
0.68
0.763
M1 + 0.1% E2
M1 + 25% E2
0.765
0.763
0.68
0.2042
0.77 ns
0
$^{95}_{42}$Mo

^{95}Zr (65 d):
β^-: β_2 **0.89** (2%), β_3 **0.396** (55%), β_4 **0.360** (43%) mag spect (DrabG55)
β_2 **0.88** (3%), β_3 **0.396** (43%), β_3 **0.364** (54%) mag spect (MitP54)
β_1 **1.13** (0.4%), β_2 **0.90** (0.9%), β_3 **0.40** (34%), β_4 **0.36** (53%), **0.25** (11%) mag spect (ZarP54)
others (CorkJ53b, SlaH53, SlaH52a, NedV51, ShpV51b)
γ: γ_1 **0.722** (e_K/γ 0.0014), γ_2 **0.754** (e_K/γ 0.0011) mag spect conv (MitP54)
γ_1 **0.723**, γ_2 **0.756** mag spect conv (ZarP54, AjzF56)
γ_1 **0.726** (e_K/γ 0.0013, K/L 9), γ_2 **0.760** (e_K/γ 0.0018, K/L 6) mag spect conv (DrabG55)
others (CorkJ53b, SlaH53, RohR55, SlaH52a, VoN60a)
$\beta\gamma(\theta)$: (MitP54)
$\beta\gamma$polariz(θ): (AppH59, MannL62, CollW65, AppH57)

^{95}Nb (35 d):
β^-: β_1 **0.924** (≈0.075%), β_2 **0.1597** (100%) mag spect (LangeL63)
others (DrabG55, FanC52, ZarP54, ShpV51b, TsvN60, SlaH53, SlaH52a, CorkJ53b, HadJ49, AjzF56, NedV51)
γ: γ_1 **0.7645** (e_K/γ 0.0011, K/L+M+... 7.5) mag spect conv (LangeL63)
γ_1 **0.770** (e_K/γ 0.0019, K/L+M+... 7.4) mag spect conv (DrabG55)
γ_1 (e/γ 0.0021) mag spect conv (StuL54)
γ_1 (e/γ 0.0016) mag spect conv (FanC52)
others (MitP54, CorkJ53b, ZarP54, JohaK56, DrabG55, MacR53, SlaH53, SlaH52a, HadJ49, AjzF56, NedV51, LalW47)
$\beta\gamma$polariz(θ): (AppH62, MannL62, CollW65)

^{95m}Nb (90 h):
γ: **0.235** (K/L+M+... ≈4.5) mag spect conv (CorkJ53b)
0.231 (e/γ very large) mag spect conv (SlaH52a, SlaH53)
0.232 (K/L+M+... ≈3.5) mag spect conv (PreiP51)
0.236 (K/L+M+... 3.7) mag spect conv (OngP54a)
0.236 (K/L+M+... 4.5) mag spect conv (DrabG55)
others (HadJ49, ShpV52, AjzF56, DolV53)


1/2+
67 h
$^{99}_{42}$Mo
β^-
Q_β - 1.37
(MTW)
0.3% 7.5
17% 6.4
1.0% 8.5
82% 7.1
65 0.94
35 0.62
1.11
(3/2+)
26 0.780
73 0.740
1 0.410
0.922
0.372
0.513
IT
79 0.181
21 0.0406
0.00215 E3
5/2+
1/2-
7/2+
3.6 ns
6.0 h
0.1811
0.1427
0.1405
M1 + E2
9/2+
0
2.12x10^5 y
$^{99}_{43}$Tc
Q_β - 0.292
(MTW)

^{99}Mo (67 h):

β^-: β_1 **1.234**, β_2 **0.88**, β_3 **0.448**, β_4 **0.25** mag spect, $\beta\gamma$ coinc (CreT65)
β_1 **1.18** (83%), β_2 **0.80** (3%), β_3 **0.41** (14%) mag spect, $\beta\gamma$ coinc (LeviC54a)
β_1 **1.23** (≈80%), β_3 **0.45** (≈20%) mag spect (BunkM50a)
β_1 **1.23** (87%), β_3 **0.54** (13%) mag spect (MedH51)
others (VarJ54, MartyN51)

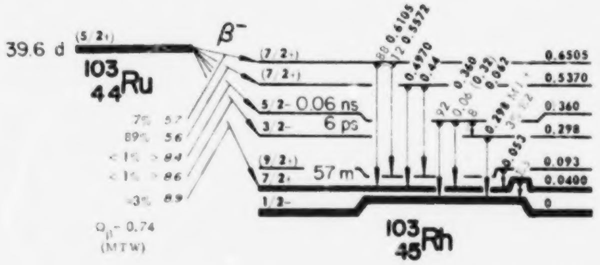
γ: γ_1 **0.0406** (I_γ 1, 0.7<e/γ<5, K/L 9.3), γ_2 **0.181** (I_γ7, e_K/γ 0.13, K/L 4.9) mag spect, mag spect conv (RavJ61)
γ_1 **0.040**, γ_2 **0.181** (γ 6.8%), γ_3 **0.372** (γ 1.3%), γ_6 **0.740** (γ 12%), γ_7 **0.780** (γ 4.4%), γ_8 **0.93** (γ 0.4%) semicond spect, scint spect (CrowP65)
γ_1 **0.041** (I_γ2), γ_2 **0.181** (I_γ6), γ_3 **0.370** (I_γ1.8) γ_4 **0.410** (I_γ0.15), γ_5 **0.62** (I_γ0.08), γ_6 **0.74** (I_γ15), γ_7 **0.78** (I_γ4), γ_8 **0.95** (I_γ0.14) scint spect, $\gamma\gamma$ coinc (CreT65)
others (BunkM50a, MartyN51, LeviC54a, MackR57, VarJ54, CapU54a, MedH51, RavJ60, BodE59a, CorkJ49a, EstI58)

$\gamma\gamma(\theta)$: (BodE59a, AndrPD65, RabS58, EstI58, CapU54a)

Isomeric level of ^{99}Mo: $t_{1/2}$ 1.3 × 10^{-5} s delay coinc (MCarA65)
1.6 × 10^{-5} s delay coinc (DufR58)
γ: **0.044**, **0.100** scint spect (MCarA65)
others (DufR58)

^{99m}Tc (6.04 h):

γ: γ_1 **0.00215** (M_I/M_{II+III}/M_{IV+V} 3/3/1) mag spect conv (FreeM57)
γ_2 **0.1405** cryst spect (ChupE58)
γ_2 **0.1403** (I_K100, K/L_I 7.7, L_I/L_{III} >10), γ_3 **0.1423** (I_K10, K/L_{III} 2.5) mag spect conv (MihJ51, MihJ52a)
γ_1 **0.0018** (e/γ very large), γ_2 **0.141** (e_K/γ 0.10, K/L 7.9) mag spect conv (MedH49, MedH51)
γ_2 **0.1405** (I_K100, K/L 8.1), γ_3 **0.1426** (I_K6.2, e/γ > 30) mag spect conv, mag spect (RavJ61)
others (BunkM50b, MartyN51, CrowP65, CreT65, LabJ56c, LabJ56a, BallR53)


39.6 d
(5/2+)
$^{103}_{44}$Ru
β^-
7% 5.7
89% 5.6
<1% >8.4
<1% >8.6
≈3% 8.9
Q_{β^-} 0.74
(MTW)
(7/2+)
(7/2+)
5/2- 0.06 ns
3/2- 6 ps
(9/2+)
7/2+ 57 m
1/2-
88 0.6105
12 0.5572
0.4970
0.44
0.360
(0.32)
0.062
92
0.06
8
0.298 M1
3
0.053
0.6505
0.5370
0.360
0.298
0.093
0.0400
0
$^{103}_{45}$Rh

^{103}Ru (39.6 d):

β^-: β_1 **0.69** (1%), β_2 **0.217** (99%) mag spect (KondE50a, KondE51c)
β_2 **0.227**, β_3 **0.119** scint spect, $\beta\gamma$ coinc (RobR58)
β_1 **0.70** (1%), **0.37** ? (<1%), β_2 **0.202** (70%), β_3 **0.128** (28%) mag spect (ForH55)
β_1 **0.68** (6%), β_2 **0.222** mag spect (MeiJ50a)
β_1 **0.72**, β_2 **0.21**, β_3 **0.11** $\beta\gamma$ coinc (MukA65)
others (DrabG55, ShpV56, SaraB55, MandeC50, HoleN48a, DRaaB54)

γ: γ_7 **0.4970** (I_γ88), γ_8 **0.5572** (I_γ0.7), γ_9 **0.6105** (I_γ6) mag spect (KarlS64)
γ_1 **0.053** (K/L 1.0), γ_3 **0.295**, γ_7 **0.498** (K/L 8), γ_9 **0.611** mag spect conv (CorkJ52b)
γ_1 0.055, γ_3 **0.297**, γ_4 **0.323**, γ_5 **0.366**, γ_7 **0.498**, γ_9 **0.610** mag spect, scint spect (ForH55)
γ_1 **0.058** (I_γ0.4), γ_3 **0.295** (I_γ0.4), γ_5 **0.357** (I_γ0.3), γ_7 **0.498** (I_γ88, K/L+M+... 8), γ_9 **0.61** (I_γ6.9, e_K/γ 0.0006) scint spect, mag spect conv, $\beta\gamma$ coinc (DRaaB54)
γ_1 **0.053** (I_γ0.7, e_K/γ 2.7), γ_2 **0.065**, γ_3 **0.297** (I_γ0.6), no γ_4 (I_γ<0.04), γ_5 **0.36**, γ_6 **0.44** (I_γ0.9), γ_7 **0.50** (I_γ88), γ_8 **0.55** (I_γ2), γ_9 **0.61** (I_γ5) scint spect, $\gamma\gamma$, $\gamma\gamma$ sum coinc (MukA65)
no γ_5 ($I_\gamma/I_\gamma(\gamma_7)$ <0.0005) $\gamma\gamma$ sum coinc (NaqS62)
γ_7 **0.498** (e_K/γ 0.0054, K/L 6), γ_9 **0.610** mag spect conv (DrabG55)
others (SaraB55, KondE50a, KondE51c, RobR58, KondE52, MeiJ50a, ShpV56, KmA52)

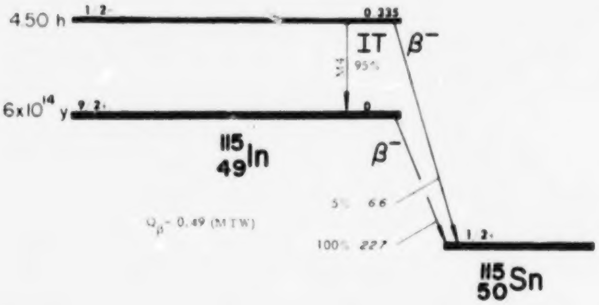
$\gamma\gamma(\theta)$: (SmB60, FlaF58)

$\beta\gamma(\theta)$: (GarwR49) $\beta\gamma$polariz(θ): (KneU65b)

isomeric level of ^{103}Ru: $t_{1/2}$ 1.7×10^{-3} s delay coinc (BranK64)
γ: **0.213** scint spect (BranK64)

^{103m}Rh (57 m):

γ: **0.0400** (K/L+M+... 0.2) mag spect conv, $\beta\gamma$ coinc (KondE50a, KondE51c, KondE52)
0.0402 (e_K/γ 40, K/L 0.09) mag spect conv (AviP55a)
0.0396 (K/L 0.1) mag spect conv (CorkJ52b)
0.040 (K/L 0.18) mag spect conv (DrabG55)
others (MeiJ50a, AviP53b, WieM45b, RogaI64)


4.50 h
1/2-
0.335
IT
β⁻
M4
95%
6x10¹⁴ y
9/2+
0
¹¹⁵₄₉In
β⁻
5% 6.6
100% 22.7
Qβ- 0.49 (MTW)
1/2+
¹¹⁵₅₀Sn

^{115}In (6 × 10^{14} y):

I: **9/2** atomic spect, atomic beam, μ: +**5.5351** NMR, q: +**1.16**, Ω: +**0.56** atomic beam (LindgI64)

β^-: **0.48** scint spect (WatD62a)
0.63 abs (MartcL50)
0.6 scint spect (BearG61a)

γ: no γ, lim 1% (WatD62a)

0.83 level of ^{115}In: $t_{1/2}$ 5.5 × 10^{-9} s delay coinc (TanP64a)
others (GoroS60c)

0.935 level of ^{115}In: $t_{1/2}$ 4 × 10^{-12} s Coulomb excit (VasiV62)

1.13 level of ^{115}In: $t_{1/2}$ 4 × 10^{-13} s if I = **13/2**, Coulomb excit (VasiV62, AndrD61a)

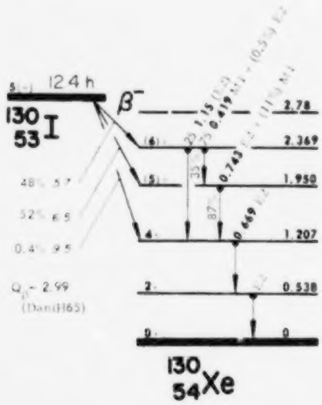
^{115m}In (4.60 h):

I: **1/2**, μ: −**0.24375** atomic beam (LindgI64)

β^-: **0.83** mag spect (BellP49)
0.84 mag spect (LangeL52a)

γ with β^-: no **0.499** γ, lim 0.4% of β^- (SchM62)

γ with IT: **0.335** (e_K/γ 0.8, K/L+M+... 3.8) mag spect conv (LangeL52a, GravG52)
0.335 (e_K/γ 0.8, K/L+M+... 3.9) mag spect conv, scint spect (VarJ55)
0.338 (e_K/γ 1, K/L 5.3) mag spect conv (LawJL40)
others (AntoI56, AntoI55, HameM56a, EstI55, LabJ56c, LabJ56b, LabJ56a)


5(+) 12.4 h
¹³⁰₅₃I
β⁻
2.78
1.15 (E2)
0.419 M1 + (0.5%) E2
E2 + (11%) M1
(6)+
2.369
35%
22%
0.743
(5)+
1.950
87%
0.669 E2
4+
1.207
48% 5.7
52% 6.5
0.4% 9.5
Qβ- 2.99 (DaniH65)
2+
0.538
E2
0+
0
¹³⁰₅₄Xe

^{130}I (12.4 h):

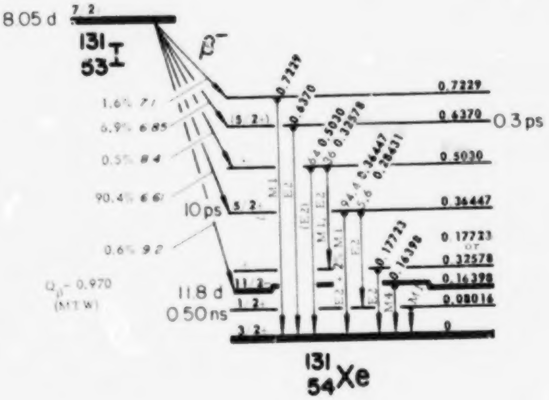
I: **5** atomic beam (LindgI64)

β^-: **1.7** (0.4%), **1.04** (48%), **0.62** (52%) mag spect (DaniH65)
others (CaiR54, RobeA43)

γ: γ_1 **0.419** (I_γ 36, e/γ 0.017), γ_2 **0.538** (I_γ 100, e/γ 0.008), γ_3 **0.669** (I_γ 100, e/γ 0.0041), γ_4 **0.743** (I_γ 87, e/γ 0.003), γ_5 **1.15** (I_γ 12, e/γ 0.0009) mag spect conv, scint spect (DaniH65)
γ_1 **0.42** (I_γ 35, e_K/γ 0.013), γ_2 **0.54** (I_γ 100, e_K/γ 0.006), γ_3 **0.67** (I_γ 99, e_K/γ 0.0032), γ_4 **0.74** (I_γ 88, e_K/γ 0.0024), γ_5 **1.15** (I_γ 13, e_K/γ 0.0007) scint spect, mag spect conv (SmiW59, CaiR54)

βγ(θ), βγpolariz(θ): (DaniH65)

γγ(θ): (SmiW59)


8.05 d
7/2+
$^{131}_{53}$I
β^-
1.6% 7.1
6.9% 6.85
0.5% 8.4
90.4% 6.6
10 ps
0.6% 9.2
Q_{β^-} 0.970
(MTW)
11.8 d
0.50 ns
(5/2+)
5/2+
11/2−
1/2+
3/2+
0.7229
0.6370
64 0.5030
36 0.32578
94.4 0.36447
5.6 0.28431
0.17723
0.16398
M1
E2
(E2)
M1, E2
M1
E2 + 2% M1
E2
M4
M1
0.7229
0.6370
0.3 ps
0.5030
0.36447
0.17723
or
0.32578
0.16398
0.08016
0
$^{131}_{54}$Xe

^{131}I (8.05 d):

J: **7.2**, μ: +**2.738**, q: −**0.40** atomic beam (LindgI64)

β^-: β_1 **0.81** (0.7%), β_2 **0.608** (87.2%), β_3 **0.33** (9.3%) β_4 **0.25** (2.8%) mag spect, βγ coinc (BellRE52a)

β_1 **0.81**, β_2 **0.606**, β_3 **0.335**, β_4 **0.250** mag spect, βγ coinc (KetB51)

β_1 (**0.81**) (0.6%), β_2 **0.606** (86%), β_3 **0.34** (13%) mag spect (VersN51)

β_1 **0.81** (1%), β_2 **0.606** (85%), β_3 **0.34** (13%) mag spect (RosD52)

others (CorkJ51, ThuS51, BellP51, FeiI50, KerB49, MetF48, DowJ42, CavP52, CavP52a, NijG51, OweG48, BelE52, CaswR52)

γ: γ_1 **0.08016**, γ_3 **0.28431**, γ_5 **0.36447** cryst spect (HoyH53, LindD49)

γ_1 **0.08016** (I_K200), γ_2 **0.17723** (I_K3.1, K/L_I/L_{II}/L_{III} 100/13/7/5), γ_3 **0.28432** (I_K16, K/L_I/L_{II}/L_{III} 100/11/3.8/3.3), γ_4 **0.32578** (I_K0.59, K/L 6), γ_5 (**0.36447**) (I_K100, K/L_I/L_{II}/L_{III} 100/11/2.5/2.2), γ_6 **0.5030** (I_K0.17, K/L > 5), γ_7 **0.6370** (I_K1.9), γ_8 **0.7229** (γ_K0.43) mag spect conv (WolfsJ62)

γ_1 **0.080** (I_γ3.1, e_L/γ 0.17), γ_2 **0.177** (I_γ0.3, e_K/γ 0.2), γ_3 **0.284** (I_γ6.6, e_K/γ 0.052, K/L+M+... 4), γ_4 **0.326** (I_γ0.3), γ_5 **0.364** (I_γ100, e_K/γ 0.020, K/L 6.0), γ_6 **0.503** (I_γ0.54), γ_7 **0.637** (I_γ8.3, e_K/γ 0.0039, K/L+M+... ≈9), γ_8 **0.723** (I_γ1.9, e_K/γ 0.004) mag spect conv, scint spect (DaniH64b)

γ_1 **0.080** (I_γ2.6, e_K/γ 1.7, K/L+M+... 6), γ_3 **0.284** (I_γ6.6, e_K/γ 0.05, K/L+M+... 4), γ_5 **0.364** (I_γ100, e_K/γ 0.018, K/L+M+... 6), γ_7 **0.637** (I_γ12, e_K/γ 0.004, K/L+M+... 7), γ_8 **0.722** (I_γ3.5, e_K/γ 0.003) mag spect mag spect conv, e^-e^- coinc, scint spect (BellRE52, BellRE52a)

others (HasJ52a, HargC63, RosD52, WolfsJ52, DzhB59, JunH63, VersN51, SmiW56, BereD60a, KerB49, CorkJ50, BergI54a, MetF48, MathG61, BereD62, ThuS51, BellP51, AlmS52, NijG54, SchiD53, CavP52, CavP52a, KetB51, CorkJ51, BrosA49, WriW51, EmeE51)

γγ(θ): (HamiW63, SchiD53)

βγ(θ): (BeysJ50a)

βγpolariz(θ): (DaniH64b) nucl align: (JohnCE60)

0.150 level of ^{131}I: $t_{1/2}$ 9×10^{-10} s delay coinc (DWaaH56, GerhT56b, DevaS65)

8×10^{-10} s delay coinc (SorA59, BedeA59a)

1.829 level of ^{131}I: $t_{1/2}$ 5.9×10^{-9} s delay coinc (DevaS65)

^{131m}Xe (11.8 d):

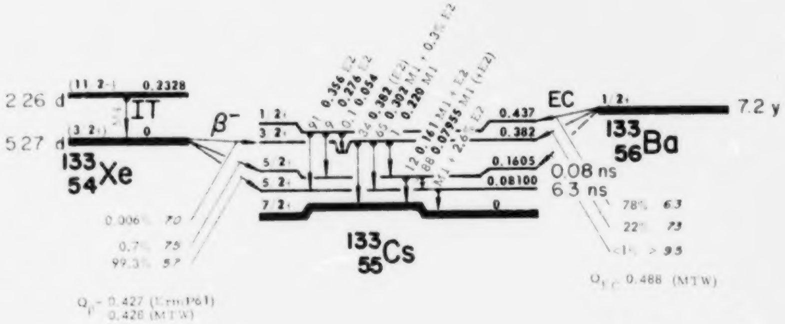
γ: γ_1 **0.16398** (K/L_I/L_{II}/L_{III} 100/27/4.5/23) mag spect conv (WolfsJ62)

γ_1 **0.16394** (K/L_I/L_{II}/L_{III} 100/24/5.5/20 mag spect conv (GeiJ62)

γ_1 **0.1639** (e_K/γ 29, K/L 2.3) mag spect conv, scint spect (BergI54, BergI52, BergI50c, BergI51a)

γ_1($I_{\gamma\gamma}$/I_γ 0.001) (AlvT60b)

others (SmiW56, VersN51, GreeA57)


2.26 d
(11/2-) 0.2328
IT
M4
5.27 d
(3/2+) 0
133 54 Xe
β⁻
0.006% 7.0
0.7% 7.5
99.3% 5.7
Q β⁻ 0.427 (ErmP61)
0.428 (MTW)
1/2+
3/2+
5/2+
5/2+
7/2+
0.356 E2
0.276 E2
0.054
0.382 (E2)
0.302 M1 + 0.3% E2
0.220 M1
0.161 M1 + E2
0.07955 M1 (+E2)
M1 + 2.6% E2
91
9
0.1
34
65
1
12
88
0
133 55 Cs
0.437
0.382
0.1605
0.08100
0.08 ns
6.3 ns
EC
1/2+
7.2 y
133 56 Ba
78% 6.3
22% 7.3
<1% >9.5
Q EC 0.488 (MTW)

^{133}Xe (5.27 d):

β^-: **0.346** mag spect (ErmP61)
others (BergI52, BergI50b)

γ: γ_1 **0.07955** (I_γ0.8, e_K/γ 1.0, K/L_I 1.7), γ_2 **0.08097** (I_γ100, e_K/γ 1.4, K/L_I/L_{II}/L_{III} 75/10.0/1.6/1.0), γ_3 **0.160** (I_γ0.11), γ_4 **0.22** ? (I_γ < 0.0004), γ_5 **0.302** (I_γ0.012), γ_6 **0.382** (I_γ0.006) mag spect conv, scint spect, $\gamma\gamma$ coinc (ErmP61)
γ_2 **0.08100** (K/L_I/L_{II}/L_{III} 75/10.0/1.5/1.1) mag spect conv (SiegK64)
γ_2 **0.08099** (K/L_I/L_{II}/L_{III} 79/10.0/1.48/1.15) mag spect conv (BrowF61)
γ_2 (e_K/γ 1.5, K/L+M+... 4.9) mag spect conv, scint spect (BergI54, BergI52, BergI50b)
γ_1 (I_γ0.4), γ_2 (I_γ100), γ_3 **0.160** (I_γ1.4), γ_5 **0.300** (I_γ0.08), γ_6 **0.380** (I_γ0.04) scint spect, $\gamma\gamma$ coinc (JhaS59)
others (GrahR53, SneA58, StewM60)

$\beta\gamma(\theta)$: (MullH60)

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^{133m}Xe (2.26 d):

γ: **0.2328** (e_K/γ 4, K/L 2.9) mag spect conv, scint spect (BergI51b, BergI54)
others (KetB51a)

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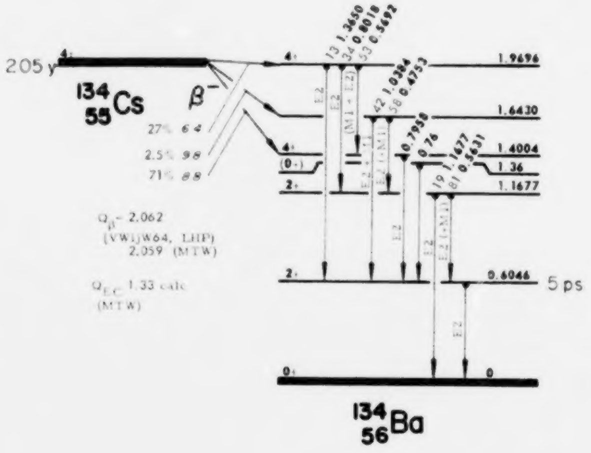
^{133}Ba (7.2 y):

γ: γ_1 **0.054** (I_γ2), γ_2 + γ_3 **0.080** (I_γ32), γ_4 **0.161**, γ_6 **0.276** (I_γ10, e_K/γ 0.047, K/L+M+... 5), γ_7 **0.302** (I_γ21, e_K/γ 0.036, K/L+M+... 6), γ_8 **0.356** (I_γ100, e_K/γ 0.021, K/L+M+... 7), γ_9 **0.383** (I_γ11, e_K/γ 0.02, K/L+M+... 5) mag spect, mag spect conv, scint spect, $\gamma\gamma$ coinc (MannK63)
γ_1 **0.054** (I_γ3), γ_2 **0.080** (I_γ9), γ_3 **0.082** (I_γ55), γ_4 **0.162** (I_γ2), γ_5 **0.220** (I_γ0.3), γ_6 **0.276** (I_γ8), γ_7 **0.301** (I_γ27), γ_8 **0.356** (I_γ100), γ_9 **0.386** (I_γ10) scint spect, $\gamma\gamma$ coinc (StewM60)
γ_1 **0.054** (γ 0.11%), γ_3 **0.081** (e_K/γ 1.35, K/L+M+... 4.8), γ_5 **0.220** (K/L+M+... 7.4) mag spect conv, scint spect, $\gamma\gamma$, $e^-\gamma$ coinc (NiesE64)
γ_1 **0.056** (I_γ7), γ_2 ($+\gamma_3$?) **0.079** (I_γ45, e_K/γ 1.5, K/L+M+... 7), γ_4 **0.160** (I_γ0.4, e_K/γ 0.4, K/L+M+... 4), γ_6 **0.277** (I_γ3, e_K/γ 0.11), γ_7 **0.302** (I_γ22, e_K/γ 0.024), γ_8 **0.356** (I_γ100, e_K/γ 0.017), γ_9 **0.383** scint spect, $\gamma\gamma$ coinc, mag spect conv (GupR58)
others (KoiS58, CrasB57, LangeM56, LangeM54a, LangeM55, RamasM60c, BureA57

$\gamma\gamma(\theta)$: (YinL64, MonF63, BodE59, AryA61, SubB61, AgarY65, ClF60)

EC decay to **0.437** level of ^{137}Cs: EC(L+M+...)/EC(K) 1.1 (RamasM60c)
others (GupR58, KoiS58, LangeM56)


2.05 y
4+
$^{134}_{55}$Cs
β^-
27% 6.4
2.5% 9.8
71% 8.8
Q_{β^-} 2.062
(VWijW64, LHP)
2.059 (MTW)
Q_{EC} 1.33 calc
(MTW)
13 1.3650
34 0.8018
53 0.5692
42 1.0384
58 0.4753
0.7958
0.76
19 1.1677
81 0.5631
E2
E2
(M1 + E2)
E2 + M1
E2 (+M1)
E2
E2
E2 (+M1)
E2
4+
(0+)
2+
2+
0+
1.9696
1.6430
1.4004
1.36
1.1677
0.6046
5 ps
0
$^{134}_{56}$Ba

Cs (2.05 y):

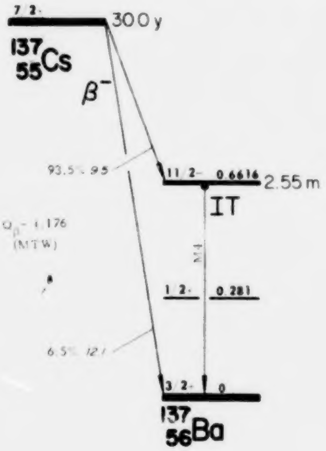
I: **4**, μ: +**2.990** atomic beam (LindgI64)

β^-: β_1 **0.662** (71%), β_2 **0.410** (1%), β_3 **0.089** (28%), no **0.21**, **0.28**, **0.34**, **0.68** β^-, no **0.89** β^- (lim 0.045%), no **1.45** β^- (lim 0.005%) mag spect (VWijW64)
others (DaniH63b, TrehP63, KeiG55, CorkJ53a, DaniH63b, ForH55a, BertG55, BertG56c, BashA54, ElliL47, GromK52, WagM50a, WolfsJ56)

γ: γ_1 **0.4753** (γ 1.5%, e_K/γ 0.009), γ_2 **0.5631** (γ 8%, e_K/γ 0.006), γ_3 **0.5692** (γ 14%, e_K/γ 0.008), γ_4 **0.6046** (γ 98%, e_K/γ 0.0048), γ_5 **0.7958** (γ 88%, e_K/γ 0.0025), γ_6 **0.8018** (γ 9%, e_K/γ 0.0026), γ_7 **1.0384** (γ 1.1%, e_K/γ 0.0016), γ_8 **1.1677** (γ 1.9%, e_K/γ 0.0010), γ_9 **1.3650** (γ 3.4%, e_K/γ 0.0007) semicond spect, mag spect conv (BrowRA65)
others (EwaG64, VWijW64, KeiG55, DzhB59e, VerhJ54, SchrS63, HankA63, TrehP63, SegO63, GirR59a, CorkJ53a, ForH55a, BertG55, JosM54, BashA54, AlekY58, OFriZ56, WagM50a, MacR53, FirsE57, ShpV51, ElliL47, JohaK56, BertG56c, LuD54, HucJ65)

$\beta\gamma(\theta)$: (GrabZ65, StevD51, BeysJ50) $\beta\gamma$polariz(θ): (DaniH63b, MannL62a, TirK65)

$\gamma\gamma(\theta)$: (MunF63, SegO63, ColeL63, StewM55, KlemE55) $\gamma\gamma$polariz(θ): (KloR52, MetF50, RobiB52)


7/2+
30.0 y
$^{137}_{55}$Cs
β^-
93.5% 9.5
11/2−
0.6616
2.55 m
IT
Q_{β^-} 1.176
(MTW)
M4
1/2+
0.281
6.5% 12.1
3/2+
0
$^{137}_{56}$Ba

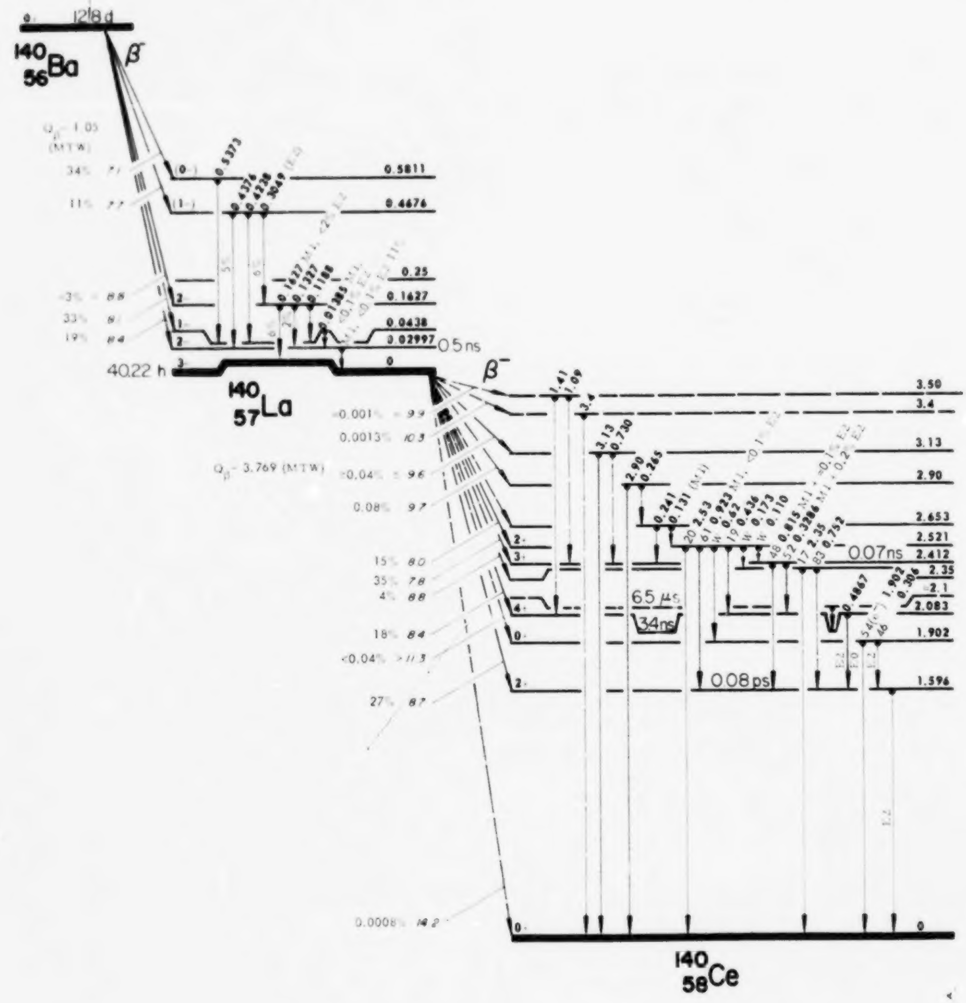
^{137}Cs (30.0 y):

I: **7/2**, μ +**2.8382** atomic beam; q: +**0.050** opt double res (LindgI64)

β^-: β_1 **1.176** (6.5%), β_2 **0.514** (93.5%) mag spect (DaniH62b)
β_1 **1.176** (7.6%), β_2 **0.514** (92.4%) mag spect (YosY58)
others (KatoT57, AgnH50, OlsJ54, LangeL51, AzuT54, WapA54a, BroyC53, PeaC49, OsoJ49, RiccR57, DrabG55, MacqP54, BosH63a, CharP65)

^{137m}Ba (2.55 m):

γ: γ_1 **0.6616** (K/L_I/L_{II}/L_{III} 1000/151/22/19) mag spect conv (GeiJ62)
γ_1 (e_K/γ 0.093, K/L+M+... 4.5) mag spect conv (DaniH62b)
γ_1 (e_K/γ 0.095) mag spect, mag spect conv (HulS61)
γ_1 (K/L/M 56/10/2.2) mag spect conv (ChuY64a)
γ_1 (K/L/M 566/100/26.0) mag spect conv (YosY58)
γ_1 (γ 86%, e/γ 0.1100) semicond spect (MerJ65)
γ_1 ($\Gamma_{\gamma\gamma}/\Gamma_\gamma$ 6 × 10^{-6}) (BeuW60)
others (MullD52, LindsG53a, GravG52, LangeL50b, DVriC60b, HulS59, SubB61c, KureT63, WapA54a, WagM51, MGowF57a, KatoT57, MacR53, AzuT54, BendW52, KruP52, MitA49, OsoJ49, TownJ48, RiccR57, VerhJ54, AntoI56a, AntoI56, DolV53, BhaS54, DrabG55, BosH63a, RaoMR65)


12.8 d
0+
140 56 Ba
β⁻
Qβ⁻ 1.05 (MTW)
34% 7.1
11% 7.7
≈3% ≈ 8.8
33% 8.1
19% 8.4
(0-) 0.5811
(1-) 0.4676
0.25
2- 0.1627
1- 0.0438
2- 0.02997
0.5 ns
3- 0
40.22 h
140 57 La
0.5373
0.4376
0.4238
0.3049 (E2)
0.1627 M1, <2% E2
0.1327
0.1188
0.01385 M1, <0.1% E2
M1, <0.1% E2, 11%
5%
6%
β⁻
≈0.001% ≈ 9.9
0.0013% 10.3
Qβ⁻ 3.769 (MTW)
≈0.04% ≈ 9.6
0.08% 9.7
15% 8.0
35% 7.8
4% 8.8
18% 8.4
<0.04% >11.3
27% 8.7
0.0008% 14.2
1.41
1.09
3.4
3.13
0.730
2.90
0.265
0.241
0.131 (M1)
2.53
0.923 M1, <0.1% E2
0.62
0.436
0.173
0.110
0.815 M1 + ≈0.1% E2
0.3286 M1 + 0.2% E2
2.35
0.752
20
61
w
19
w
w
48
52
17
83
0.4867
1.902
0.306
54(e⁻)
46
E2
E0
E2
E2
6.5 μs
34 ns
0.07 ns
0.08 ps
2+
3+
4+
0+
2+
0+
3.50
3.4
3.13
2.90
2.653
2.521
2.412
2.35
≈2.1
2.083
1.902
1.596
0
140 58 Ce

^{140}Ba (12.8 d):

β^-: $\beta_1 + \beta_2$ **1.02**, β_3 **0.83**, β_4 **0.59**, β_5 **0.46** mag spect, $\beta\gamma$ coinc (BosP59a)
$\beta_1 + \beta_2$ **1.02** (60%), β_4 **0.48** (40%) mag spect (BeacL49b)
β_1 **1.03**, β_2 **1.02** (β_1/β_2 0.6) $\beta\gamma$ coinc (BurdJ65)
others (WilkR51)

γ: γ_1 **0.01385**, γ_2 **0.02997**, γ_3 **0.1188**, γ_4 **0.1327**, γ_5 **0.1627**, γ_6 **0.3049**, γ_7 **0.4238**, γ_8 **0.4376**, γ_9 **0.5373** mag spect conv, $e^-\gamma$, $\gamma\gamma$ coinc (GeiJ61a)
γ_2 **0.0296** (I_L 23, $L_I/L_{II}/L_{III}$ 20/2/1), γ_3 **0.119** (I_K 1), γ_4 **0.132** (I_K 4), γ_5 **0.162** (I_K 10, K/L 2), γ_6 **0.304** (I_K 4), γ_7 **0.421** (I_K 1), γ_8 **0.436** (I_K 1), γ_9 **0.537** (I_K 4, K/L 4) mag spect conv (CorkJ51d)
γ_2 **0.030** (γ 13%), γ_4 **0.132** (γ 1.7%), γ_5 **0.162** (γ 8%), γ_6 **0.304** (γ 7%), γ_8 **0.436** (γ 5%), γ_9 **0.536** (γ 29%) scint spect (AgarY64)
γ_2 **0.0296**, γ_4 **0.131** (I_γ 1.4), γ_5 **0.162** (I_γ 10, K/L+M+… ≈3.8), γ_6 **0.304** (I_γ 5), γ_8 **0.436** (I_γ 5), γ_9 **0.537** (I_γ 25) scint spect, $\gamma\gamma$ coinc, mag spect conv (BosP59a)
γ_2 **0.030** (γ 16%, e/γ 5), γ_4 **0.132** (γ 3%), γ_5 **0.162** (γ 5%), γ_6 **0.304** (γ 3%), γ_8 **0.436** (γ 5%), γ_9 **0.537** (γ 25%) scint spect (DuzB61, SilA58)
γ_9 (e_K/γ 0.006, K/L+M+… 5.2) mag spect, mag spect conv (RohR55)
others (KellWH56, MacR53, BeacL49b, BurdJ65)

$\beta\gamma(\theta)$: (AgarY64)

$\gamma\gamma(\theta)$: (AgarY64, BlacW63, KellWH56, BurdJ65, ZukW65)

^{140}La (40.22 h):

I: **3** atomic beam (Lindgl64)

β^-: β_1 **2.175** (6%), β_2 **1.68** mag spect (LangeL60)
β_1 **2.15** (7%), β_2 **1.67** (10%), β_3 **1.34** (45%), β_4 **1.10** (26%), β_5 **0.83** (12%) mag spect (PeaC54)
β_1 **2.20** (8%), β_2 **1.62** (14%), β_3 **1.36** (30%), β_4 **1.15** (20%), β_5 **0.86** (12%), β_6 **0.42** (16%) mag spect (BashA54a, AjzF56)
3.8 (0.0008%), β_1 **2.20** (10%) mag spect (DzhB60a)
others (WilkB51a)

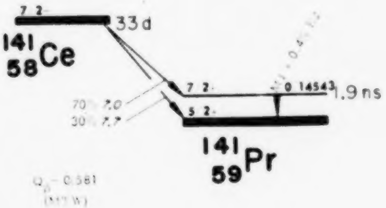
γ: γ_1 **0.0687** (K 0.010%), γ_2 **0.109** (K 0.013%, K/L 2), γ_3 **0.110** (K 0.002%), γ_4 **0.131** (K 0.10%, K/L 9), γ_5 **0.173** (K 0.011%), γ_6 **0.241** (K 0.008%), γ_7 **0.265** (K 0.011%), γ_9 **0.329** (K 0.59%, e_K/γ 0.029, K/L 6.2), γ_{10} **0.436** (K 0.024%, e_K/γ 0.010), γ_{11} **0.487** (K 0.37%, e_K/γ 0.009, K/L 7.0), γ_{12} **0.730** (K 0.010%), γ_{13} **0.752** (K 0.015%, e_K/γ 0.003), γ_{14} **0.815** (K 0.094%, e_K/γ 0.005, K/L 8), **0.868** (γ 5%), γ_{15} **0.923** (K 0.014%, e_K/γ 0.0014, K/L 8), γ_{18} **1.597** (K 0.059%, e_K/γ assumed 0.00069, e^+/e_K 16), γ_{19} **1.91** (K 0.013%, $e_K/\gamma > 0.38$, K/L 6.3), γ_{20} **2.34** (K 0.00027%, e_K/γ 0.0004, K/L 6.6, e^+/e_K 116), γ_{21} **2.53** (K 0.0012%, e_K/γ 0.0003, K/L 6.3, e^+/e_K 105), γ_{22} **2.90** (K 0.000022%, e_K/γ 0.0003), γ_{23} **3.13** (K 6×10^{-6}%, e_K/γ 0.0002), γ_{24} **3.4** (γ 0.0013%) mag spect conv, mag spect (BashA58, PriV58, CorkJ51e, PriV58a, DzhB60a, DzhB60f, AntoS60a)
γ_9 **0.3286**, γ_{11} **0.4867**, γ_{14} **0.815**, γ_{18} **1.596** mag spect (HedA52)
γ_9 **0.328** (I_γ 38, e_K/γ 0.035, K/L+M+... 7), γ_{10} **0.438** (I_γ 6), γ_{11} **0.490** (I_γ 48, e_K/γ 0.008, K/L+M+... 7), γ_{14} **0.815** (I_γ 44, e_K/γ 0.004), γ_{18} **1.60** (I_γ 96, e_K/γ 0.0008), γ_{21} **2.50** (I_γ 1), $\gamma_{22}+\gamma_{23}$ **3.00** (I_γ 0.04) mag spect conv, scint spect, $\gamma\gamma$ coinc (BelH55)
γ_{18} **1.598** (γ 96%), γ_{19} (**1.9**) (γ < 0.15%), γ_{20} **2.37** (γ 0.8%), γ_{21} **2.53** (γ 3.0%), γ_{22} **2.89** (γ 0.08%), γ_{23} **3.10** (γ 0.03%), γ_{24} (**3.25**) (γ < 0.005%) 3 cryst pair spect (HansP62a)
γ_8 **0.31** (coinc γ_{18}), γ_{11} **0.49**, γ_{14} **0.814**, γ_{16} **1.09** (coinc γ_{14}), γ_{17} **1.41** (coinc γ_{11}) $\gamma\gamma$ sum coinc (NaqS62)
0.62 (coinc γ_{19}) $e^-\gamma$ coinc (SalP65)
others (TakekH61, CorkJ51e, BanR51, ColeC55, RohR55, MackR57, PeaC54, BashA54a, DzhB56f, SimoL63b, ArkL55, ArkV59, ArkV57, KhoE58, MacR53, BearL49b, RalW47, MillL46, RobiB51a, BisG50, WatA47)

$\beta\gamma(\theta)$: (AlbeJL63, BhaS63, NewR64, PetuA62, RudV60, RagR65, SubM65)

$\beta\gamma$polariz(θ): (PetuA62, KatI62)

$\gamma\gamma(\theta)$: (BlasW63, DorL63, BisG55a, KellWH56, BolH55, RobiB51a, ColeC55, KorH63a, ColeC58, SimoL63b, SchmM64)

0.030 level of ^{140}La: $t_{1/2}$ 5×10^{-10} s delay coinc (BurdJ65)



^{141}Ce (33 d):

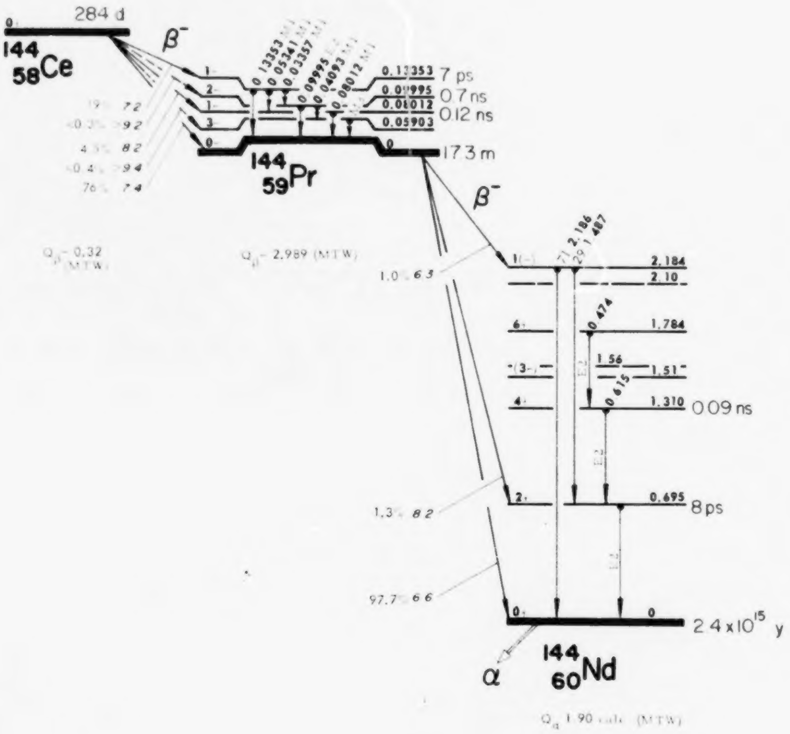
I: **7/2** ESR, nucl align; μ: ±**0.97** ESR (Lindgl64)

β^-: β_1 **0.582** (30%), β_2 **0.444** (70%) mag spect (KondL52, KondE51b, KondE51c)
β_1 **0.581** (33%), β_2 **0.442** (67%) mag spect (FreeM50a)
β_1 **0.574** (25%), β_2 **0.432** (75%) scint spect, $\beta\gamma$ coinc (JonJT55)
β_1 **0.591** (33%), β_2 **0.447** (67%) mag spect (ZorG57)
others (JosM58, ShepL48a, TPogM49)

γ: γ_1 **0.14543** (K/L_I/L_{II}/L_{III} 810/100/8.1/1.7) mag spect conv (GeiJ65a)
γ_1 (e_K/γ 0.38) scint spect (NemL61)
γ_1 (e_K/γ 0.40) scint spect (CookJ61)
γ_1 (K/L 6.4) mag spect conv (JonJT55)
γ_1 (e_K/γ 0.37, K/L 6.2) scint spect, mag spect conv (ZorG57)
others (RaoG63b, JosM58, KondE52, KondE51b, KondE51c, FreeM50a, JohaS52, HillR51a, KellH51, TPogM49, ShepL48a, WalthA65, MartiDW56)

$\beta\gamma(\theta)$, $\beta\gamma$polariz(θ): (DeuJ61a, RudV60, RaoW65)

nucl align: (GracM62, HaaJ63, HaaJ64, SchoJ62, AmbE57, CacC55, HopD61)


0
284 d
144
58Ce
β⁻
19% 7.2
<0.3% >9.2
4.5% 8.2
<0.4% >9.4
76% 7.4
1-
2-
1-
3
0-
0.13353 M1
0.05341 M1
0.03357 M1
0.09995 E2
0.04093 M1
0.08012 M1
0.13353
0.09995
0.08012
0.05903
7 ps
0.7 ns
0.12 ns
0
17.3 m
144
59Pr
Qβ- 0.32 (MTW)
Qβ- 2.989 (MTW)
β⁻
1.0% 6.3
1(-)
2.186
2.184
2.10
6+
0.474
1.784
(3-)
1.56
1.51
4+
0.615
1.310
0.09 ns
E2
E2
1.3% 8.2
2+
0.695
8 ps
E2
97.7% 6.6
0+
0
2.4x10¹⁵ y
α
144
60Nd
Qα 1.90 calc (MTW)

^{144}Ce (284 d):

β^-: β_1 **0.309** (76%), β_3 **0.175** (24%) mag spect, $\beta\gamma$ coinc (PulI56)

β_1 **0.304** (70%) mag spect (PortF52, EmmW54)

β_1 **0.32** (65%), β_2 **0.24** (5%), β_3 **0.18** (30%) mag spect (HicR58)

β_1 **0.33** (75%), β_2 **0.26** (≈5%), β_3 **0.16** (20%) mag spect (CorkJ54b)

others (FreeN59a, ParfV57, SenA59, VasiT62, ForN62, NedV51b, RobiR58, DaniH65a)

γ: γ_1 **0.03357** (L_1 0.77%, $L_I/L_{II}/L_{III}$ 100/<6/<5), γ_2 **0.04093** (L_I 0.68%, $L_I/L_{II}/L_{III}$ 100/9/<4), γ_3 **0.05341** (L_I 0.10%, $L_I/L_{II}/L_{III}$ 100/8/<6), γ_4 **0.05903** (L_I 0.22%, $L_I/L_{II}/L_{III}$ 65/11/100), γ_5 **0.08012** (K 3.3%, K/$L_I/L_{II}/L_{III}$ 100/12.4/0.8/<0.4), γ_6 **0.09995** (K 0.050%, K/$L_I/L_{II}/L_{III}$ 100/12/22/23), γ_7 **0.13353** (K 5.3%, K/$L_I/L_{II}/L_{III}$ 100/12.8/0.95/0.23) mag spect conv, $e^-\gamma$, $\gamma\gamma$ coinc (GeiJ60, GeiJ61)

γ_5 (I_γ33), γ_7 (I_γ100) scint spect (ZukW63)

γ_5 (I_γ32, e_K/γ 1.4), γ_7 (I_γ100, e_K/γ 0.8) scint spect, mag spect conv (HicR58)

note: additional transitions reported by GneA59, ForN59, FreeN59a, SenA59, ForN62, ParfV57, and IwaT63 are of doubtful existence
others (CorkJ54b, PulI56, PortF52, EmmW54, PortF59, SilA61a, VasiT62, GneA59, FreeN59a, ForN59, ParfV57, ForN62, IwaT63, KellH51, KreW54, KellWC52)

$\beta\gamma(\theta)$: (CreL63, CollW63,

$\gamma\gamma(\theta)$: (ZukW63, IwaT63, BhaR63b)

^{144} (17.3 m):

β^-: β_1 **2.996** (97.8%, β_2 **2.30** (1.2%), β_3 **0.807** (1.0%) mag spect, $\beta\gamma$ coinc (PortF59)

β_1 **2.98** (97.7%), β_2 **2.30** (1.3%), β_3 **0.80** (1.0%) mag spect, $\beta\gamma$ coinc (GrahR58)

others (EmmW54, PortF52, LanM56, HicR58, CorkJ54b, AlbuD52b, FreeN59)

γ: γ_1 **0.697** (I_γ100), γ_2 **1.487** (I_γ19), γ_3 **2.186** (I_γ49) scint spect (MonaJ61a)

γ_1 **0.697** (γ 1.5%), γ_2 **1.49** (γ 0.29%), γ_3 **2.19** (γ 0.7%) scint spect (PortF59)

γ_1 **0.69** (γ 1.6%), γ_2 **1.49** (γ 0.26%), γ_3 2.18 (γ 0.8%) scint spect (GrahR58)

others (FreeN59, HicR58, BurmV59a, SugiyK61, PortF52, AlbuD52b, CorkJ54b, EmmW54, KreW54, FireL57)

$\beta\gamma(\theta)$: (GrahR58, HessR63, RagR63, CollW63, CreL63, LobV61c)

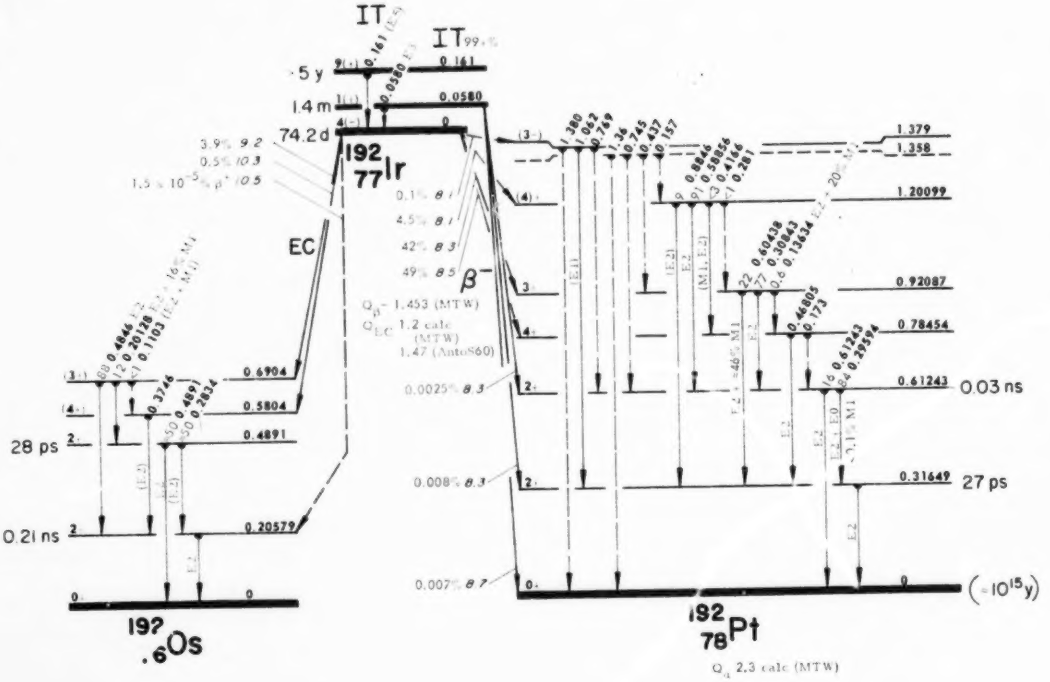
$\beta\gamma$polariz(θ): (HessR63, CollW63)

$\gamma\gamma(\theta)$: (ZukW63, GrahR58, SugiyK61)

0.080 level of ^{144}Pr: $t_{1/2}$ 1.2 × 10^{-10} s delay coinc (BurdJ62, BurdJ62a)

0.100 level of ^{144}Pr: $t_{1/2}$ 7 × 10^{-10} s delay coinc (BerlE64, BurdJ62, BurdJ62a)

0.134 level of ^{144}Pr: $t_{1/2}$ ≈7 × 10^{-12} s delay coinc (BurdJ62, BurdJ62a)


IT
IT99%
~5 y
1.4 m
74.2 d
0.161
0.0580
0
$^{192}_{77}$Ir
3.9% 9.2
0.5% 10.3
1.5 × 10⁻⁵% β⁺ 10.5
EC
0.1% 8.1
4.5% 8.1
42% 8.3
49% 8.5
β⁻
Q_{β^-} 1.453 (MTW)
Q_{EC} 1.2 calc (MTW)
1.47 (AntoS60)
0.0025% 8.3
0.008% 8.3
0.007% 8.7
0.6904
0.5804
0.4891
0.20579
0
28 ps
0.21 ns
0.4846 E2
0.20128 E2+16% M1
0.1103 (E2+M1)
0.3746
0.489
0.2834
$^{192}_{76}$Os
1.379
1.358
1.20099
0.92087
0.78454
0.61243
0.31649
0
0.03 ns
27 ps
(≈10¹⁵y)
1.380
1.062
0.769
1.36
0.745
0.437
0.157
0.8846
0.58856
0.4166
0.281
0.60438
0.30843
0.13634 E2+20% M1
0.46805
0.173
0.61243
0.29594
E2+<46% M1
E2+E0
E2
$^{192}_{78}$Pt
Q_α 2.3 calc (MTW)

^{192}Ir (74.2 d):

I: **4** atomic beam (LindgI64), μ: ±**1.9** nucl align (CamJ64b)

β^-: β_1 **0.672** (46%), β_2 **0.536** (41%), β_3 **0.24** (8%) mag spect, βγ coinc (JohnM65)

β_1 **0.67** mag spect (LevyP47a, BagL55, JohnM54a, BashA52)

β_1 **0.66** mag spect (ShpV51c)

β^+: **0.24** (1.5 × 10^{-5}%) mag spect (AntoS60)

γ with β^-: γ_1 **0.13634** (I_γ2.7, e_K/γ 0.6, K/L_I/L_{II}/L_{III} 4.9/1/3.2/2.3), γ_2 **0.29594** (I_γ360, e_K/γ 0.064, K/L_I/L_{II}/L_{III} 8.6/1/1.59/0.9), γ_3 **0.30843** (I_γ370, e_K/γ 0.060, K/L_I/L_{II}/L_{III} 7.5/1/1.47/0.66), γ_4 **0.31649** (I_γ1000, e_K/γ 0.054, K/L_I/L_{II}/L_{III} 7.9/1/1.39/0.76), γ_5 **0.4166** (I_γ≈3, e_K/γ ≈0.09), γ_6 **0.46805** (I_γ600, e_K/γ 0.021, K/L_I/L_{II}/L_{III} 7.4/1/0.75/0.32), γ_7 **0.58856** (I_γ49, e_K/γ 0.014, K/L_{I+II} 3.5), γ_8 **0.60438** (I_γ105, e_K/γ 0.019, K/L_I/L_{II}/L_{III} 6.1/1/0.24/0.04), γ_9 **0.61243** (I_γ70, e_K/γ 0.011, K/L_{I+II} 4.8), γ_{10} **0.8846** (I_γ5, e_K/γ 0.004, K/L+M 4), γ_{11} **1.062** (I_γ0.5, e_K/γ ≈0.0006) mag spect, cryst spect, mag spect conv (compiled from LindsB63, MarinL60, MurG61, HulS61, KerJ62, BagL55, HerrlC64, MurG65 by LHP)

possible weak additional γ's: **0.1560** (CorkJ51b, HarmB64), **0.173** (CorkJ51b, JohnM54a), **0.281** (I_γ13 (JohnM54a)), (I_γ<1 (LindsB63)), (HarmB64), **0.400** (CorkJ51b, ShpV51c, BashA52), **0.438** (I_γ6.5 (JohnM54a)), (I_γ<0.6 (KerJ62)), (CorkJ51b, GlazM55, ShpV51c, BashA52), **0.745** (JohnM54a, ?KerJ62), **0.769** (KerJ62), **0.785** (I_γ1 (BagL55)), (I_γ<0.02 (KerJ62)), (JohnM54a, MlaM60, PriR54), **1.056** (KerJ62, DzhB56, AntoS60), **1.091** (KerJ62, AntoS60), **1.157** (JohnM54a, not observed by DelN56, AntoS60, KerJ62), **1.21** (PriR54, not observed by DelN56, AntoS60), **1.36** (DelN56, AntoS60), **1.380** (KerJ62)

others (BagL55, MlaM60, FreyW62, HamiJ62, BergP60, KelmV57c, KerJ62, MarinL60a, MullD52, KelmV57a, JohnM54a, RomV58, RydN55, SunO57, SunO57a, AntoS60, BashA52, ShpV51c, CorkJ51b, HarmB64, WolfsJ50a, GrarF55, GlazM55, DzhB56, DzhB56f, LuD54, KelmV64)

γγ(θ) with β^-: (BattD62a, SimoT62, BattD60, KawM58, TayH55, KellWH56, ShirV57, MraI57, BagL55, JohnM65)

β^-γ(θ): (DeuJ58, GarwR49)

γ with EC: γ_1 **0.20128** (I_γ≤6, e_K/γ 0.23, K/L_I/L_{II}/L_{III} 6.5/1/1.61/1.07), γ_2 **0.20579** (I_γ38, e_K/γ 0.16, K/L_I/L_{II}/L_{III} 11/1/2.75/1.83), γ_3 **0.2834** (I_γ4, e_K/γ 0.06), γ_4 **0.3746** (I_γ6, e_K/γ 0.05), γ_5 **0.4846** (I_γ40, e_K/γ 0.018), γ_6 **0.4891** (I_γ4, e_K/γ ≈ 0.018) mag spect, cryst spect, mag spect conv (compiled from MarinL62, LindsB63, BergP60, KerJ62, HerrlC64, KelmV57c by LHP)

possible weak additional γ: **0.1103** (K/K(0.317 γ) 0.006, K/L_I/L_{III} = 7/3/2) mag spect conv (HarmB64)

0.110 (K/K(0.317 γ) 0.008) mag spect conv (MarinL62)

others (BagL55, BergP60, MarinL60, KerJ62, KelmV57c, JohnM54a, MullD52, SunO57, BashA52, ShpV51c, CorkJ51b, WolfsJ50a)

γγ(θ) with EC: (ShirV57)

^{192m_1}Ir (1.4 m):

β^-: **1.5** (0.007%), **1.2** (0.008%), **0.9** (0.0025%) βγ coinc (SchaG61)

γ with IT: γ_1 **0.0580** (L_{II}/L_{III} 1.1) mag spect conv (MizJ54)

γ_1 (e/γ 3500) (SchaG61)

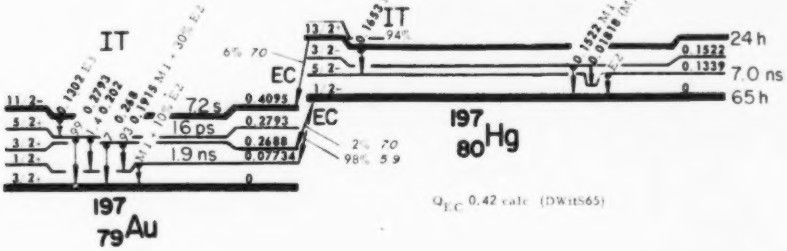
γ_1 (e/γ 1300) scint spect, scint spect conv (HennH60a)

others (CaldR50, WebG53, KeiB63, HoleN48b)

γ with β^-: **0.317**, **0.612** βγ coinc (SchaG61, SchaG59)

^{192m_2}Ir (>5 y):

γ: **0.161** (K/L = 0.06) scint spect conv (SchaG59)


IT
0.1302 E3
0.2793
0.202
0.268
0.1915 M1 + 30% E2
M1 + 10% E2
99
1.4
7
93
11/2-
5/2+
3/2+
1/2+
3/2+
72 s
16 ps
1.9 ns
0.4095
0.2793
0.2688
0.07734
0
197
79Au
6% 7.0
EC
EC
2% 7.0
98% 5.9
13/2+
3/2-
5/2-
1/2-
.1653 M4
IT
94%
0.1522 M4
0.01818 (M1)
E2
0.1522
0.1339
0
24 h
7.0 ns
65 h
197
80Hg

Q_{EC} 0.42 calc (DWitS65)

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^{197}Hg (65 h):

I: **1/2** atomic spect, opt pump; μ: **+0.52406** opt pump (LindgI64)

γ: γ_1 **0.07734** cryst spect (MarkI63)

γ_1 **0.0773** (I_{L_I}100, $L_I/L_{II}/L_{III}$ 100/44/41), γ_2 **0.1915** (I_K1.6) mag spect conv (JunB61)

γ_1 **0.0775** ($L_I/L_{II}/L_{III}$ 100/44/33), γ_2 **0.1916** mag spect conv (VHeeI59)

γ_2 **0.191** (I_γ100), γ_3 **0.268** (I_γ8), no **0.279** γ (I_γ <2) semicond spect (HavA65)

γ_1 **0.077** (I_γ34, $e_{L+M+...}/\gamma$ 4), γ_2 **0.191** (I_γ1.0, e_K/γ 0.8, K/L+M+... 4), γ_3 **0.269** (I_γ0.06) scint spect, semicond spect conv, mag spect conv (HelmeR65)

others (MihJ53, JolyR55, HubeO53, CorkJ52, HubeO51, FrauH50a)

EC to **0.269** level of ^{197}Au: EC(K)/EC(K+L+...) 0.5 (DWitS65)

0.134 level of ^{197}Hg: $t_{1/2}$ 7.0 x 10^{-9} s delay coinc (SutT61)
others (MGowF50, DeuM50)

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^{197m}Hg (24 h):

I: **13/2** atomic spect; μ: **−1.032** (LindgI64)

γ with IT: γ_1 **0.1340** ($K/L_I/L_{II}/L_{III}$ 13/2.6/15/10), γ_2 **0.1653** ($K/L_I/L_{II}/L_{III}$ 47/54/13/100) mag spect conv (VHeeI59)

γ_1 (I_K100, e_K/γ 0.5, K/L 0.40), γ_2 (I_K145, e/γ >19, K/L 0.44) mag spect conv, γγ coinc (HubeO51, FrauH50a)

γ_1 ($L_I/L_{II}/L_{III}$ 0.4/11/10), γ_2 ($L_I/L_{II}/L_{III}$ 10/<1/15) mag spect conv (MihJ53)

γ_1 (I_γ100), γ_2 (I_γ1.0) semicond spect (HavA65)

others (CorkJ52, BradC54, CobH57, HelmeR65)

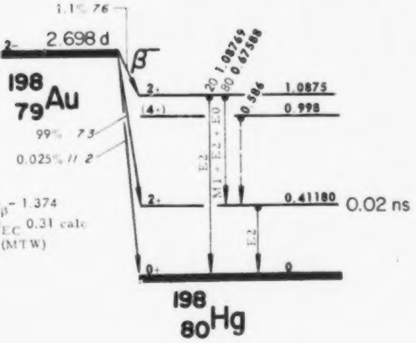
γγ(θ): (PettB61b, GerhT62.., GimF56, CobH57)

γ with EC: γ_1 **0.1302** (I_K1.6, L_{II}/L_{III} 1.3, L_I weak), γ_3 **0.2793** (I_K5) mag spect conv (MihJ53, VHeeI59, JolyR55)

γ_2 **0.202** (I_γ/I_γ(0.134 γ) 0.23), γ_3 **0.279** (I_γ/I_γ(0.134 γ) 16) semicond spect (HavA65)

others (HubeO51, BradC54, HelmeR65)

γγ(θ): (PettB61b)



^{198}Au (2.698 d):

I: **2**, μ: **±0.6** atomic beam (LindgI64)

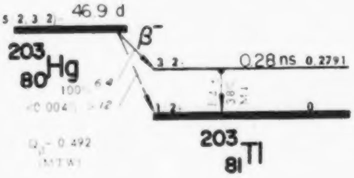
β^-: β_1 **1.371** (0.025%) mag spect (ElliL54, ElliL55)
β_2 **0.961** mag spect (PauH65)
β_2 **0.959** mag spect (BeeH65)
β_2 **0.962** mag spect (ChabM61, DepP61)
β_3 **0.29** mag spect, βγ coinc (BrosA51a)
others (PortF56, ElliL54, WapA59, DVriC60b, SaxD48, BroyC53, LangeL49, PohA54, LevyP49, StefR49, ShavL49, CavP51, WolfsJ52a, BurgN61, KeeW65, CharP65)

γ: γ_1 **0.41180** mag spect (MurG63)
γ_2 **0.67588**, γ_3 **1.08769** mag spect conv (KayG64)
γ_1 (e_K/γ 0.0299) mag spect conv (PauH65, KeeW65)
γ_1 (e_K/γ 0.0302) mag spect, mag spect conv (BergK65)
γ_1 (e_K/γ 0.0300) mag spect conv, βγ coinc (LewinW63)
γ_1 ($K/L_I/L_{II}/L_{III}$ 687/100/101/45) mag spect conv (HerrlC64)
γ_1 (I_γ100), γ_2 (I_γ0.8, e_K/γ 0.022, K/L 5.7), γ_3 (I_γ0.17, e_K/γ 0.0045, K/L 6.3) mag spect, mag spect conv (ElliL54)
γ_1 (I_γ100), γ_2 (I_γ1.1), γ_3 (I_γ0.26) mag spect (DzhB55a)
γ_1 (I_γ100), γ_2 (I_γ1.0, e_K/γ 0.019), γ_3 (I_γ0.16, e_K/γ 0.0045) mag spect, mag spect conv (VolJ56)
others (KelmV59, HameB61a, BergP60, DVriC60a, MullD52, HedA52, DMonJ48, LindD51, ConnDR56, PettB61c, HulS61, WolfsJ61a, WapA59, FreyW62, HamiJ62a, SaxD49, SiegK49b, StefR49, HubeP51, FanC52, SimoL52a, ReitD58, BirkR55, HillR50, MacD54, DzhB56f, CavP51, CavP51a, MihJ52a, SwanJ53b, KureT63, PriR50a, ShavL49, BrosA51a, StarS63, ReidyJ65a, ChenT64, ParsD64, BacksG58, PettB65a)

γγ(θ): (SakM64a, SchifD53, SchrC53, SchrC53a, MaliS59)

βγ(θ): (PettB62, StefR61, ENesM62d, GarwR49, LehJ62, LobV62b, ThuJ64a, DeiW65, LacJ65)

βγpolariz(θ): (StefR60, DeuJ61b, DCroM60, SimmP58, AvaR62, BoeF56, BertJ57, VKliJ64)

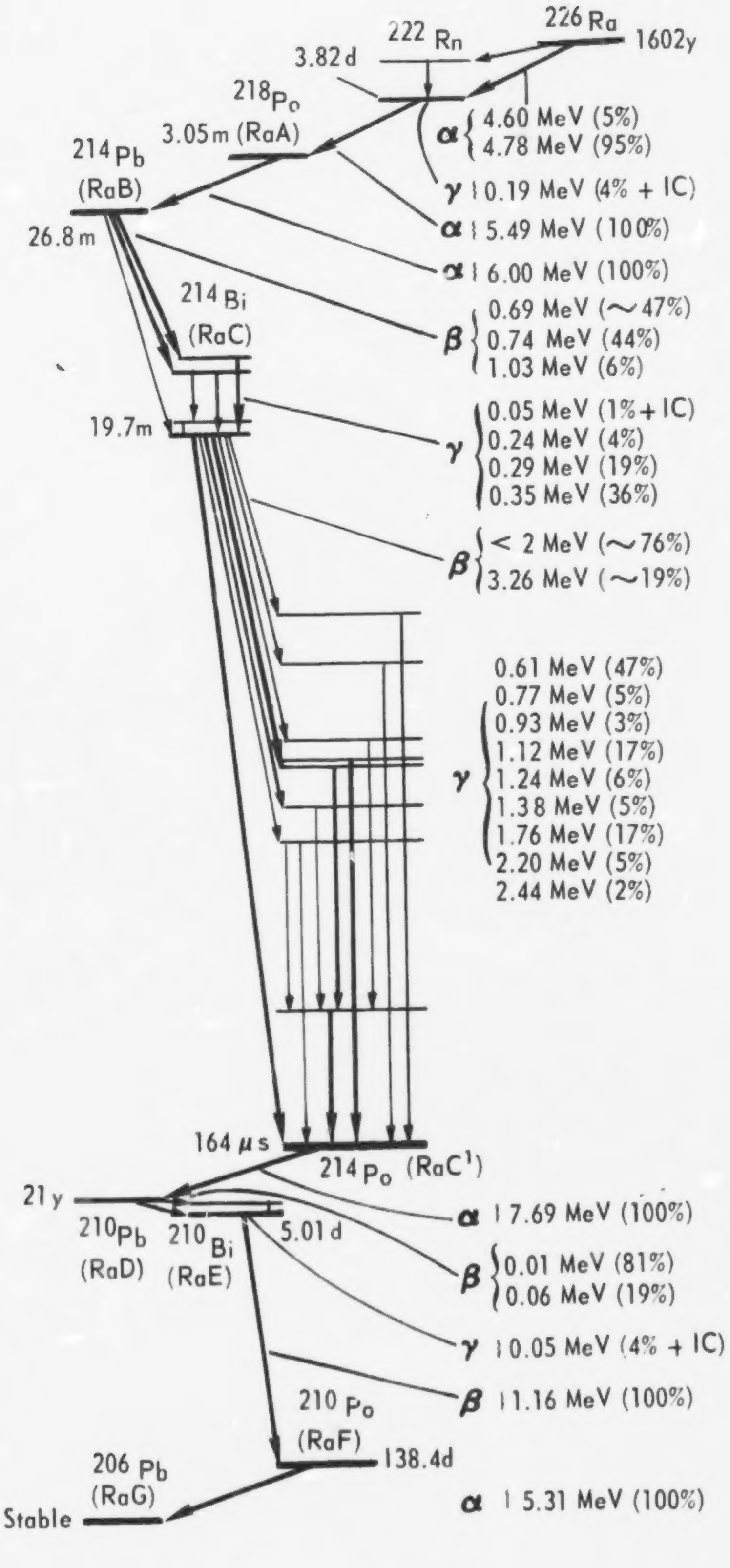


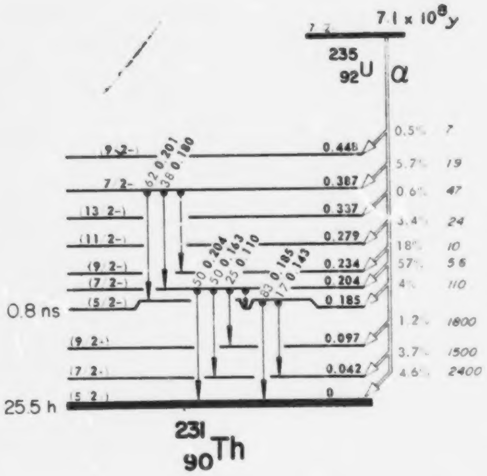
^{203}Hg (46.9 d):

β^-: **0.214** mag spect (MartyN55, NijG59)
0.210 mag spect (ThuS54a, WilsH51)
0.208 mag spect (SlaH49a, SlaH49)
no **0.49** β^- (lim 0.004%) mag spect (MartyN55)
others (SaxD48a, WolfsJ56, WapA54d, WieM47)

γ: γ_1 **0.2791** mag spect conv (EdvK58)
γ_1 (e/γ 0.226) scint spect, βγ coinc (TayJ62)
γ_1 (e_K/γ 0.162) scint spect, βγ coinc (CrofW63)
γ_1 (e_K/γ 0.163, K/L/M+... 3.39/1/0.30) mag spect conv (NijG59)
γ_1 (e_K/γ 0.159, $K/L_I/L_{II}/L_{III}$ 1/0.16/0.10/0.053) mag spect conv (NorC56)
γ_1 ($L_I/L_{II}/L_{III}$ 0.15/0.11/0.053) mag spect conv (SwanJ53b, SwanJ53a)
others (SlaH49, SlaH49a, HedA50, WolfsJ56, WilsH51, MartyN55, JohaS52, BergI53, ThuS54a, SubB61c, HurJ61, RamasM60a, OFriZ56, WapA54d, SacD48a, BurmR63, KureT63, DWaaH55b, DWaaH56, WalthA65, RaoMR65)

Isomeric level of ^{203}Hg: $t_{1/2}$ 2.1 × 10^{-5} s delay coinc (BranK64)
γ: **0.33**, **0.58** scint spect (BranK64)


226 Ra
1602y
222 Rn
3.82 d
218 Po
3.05 m (RaA)
214 Pb
(RaB)
26.8 m
α { 4.60 MeV (5%)
4.78 MeV (95%)
γ | 0.19 MeV (4% + IC)
α | 5.49 MeV (100%)
α | 6.00 MeV (100%)
214 Bi
(RaC)
19.7m
β { 0.69 MeV (~47%)
0.74 MeV (44%)
1.03 MeV (6%)
γ { 0.05 MeV (1% + IC)
0.24 MeV (4%)
0.29 MeV (19%)
0.35 MeV (36%)
β { < 2 MeV (~76%)
3.26 MeV (~19%)
0.61 MeV (47%)
0.77 MeV (5%)
0.93 MeV (3%)
γ { 1.12 MeV (17%)
1.24 MeV (6%)
1.38 MeV (5%)
1.76 MeV (17%)
2.20 MeV (5%)
2.44 MeV (2%)
164 μs
214 Po (RaC¹)
21 y
210 Pb
(RaD)
210 Bi
(RaE)
5.01 d
α | 7.69 MeV (100%)
β { 0.01 MeV (81%)
0.06 MeV (19%)
γ | 0.05 MeV (4% + IC)
β | 1.16 MeV (100%)
210 Po
(RaF)
138.4d
206 Pb
(RaG)
Stable
α | 5.31 MeV (100%)


7/2
7.1 x 10⁸y
235 92U
α
(9/2-)
7/2-
(13/2-)
(11/2-)
(9/2-)
(7/2-)
(5/2-)
(9/2-)
(7/2-)
(5/2-)
0.8 ns
25.5 h
62 0.201
38 0.180
50 0.204
50 0.163
25 0.110
83 0.185
17 0.143
0.448
0.387
0.337
0.279
0.234
0.204
0.185
0.097
0.042
0
0.5% 7
5.7% 19
0.6% 47
3.4% 24
18% 10
57% 5.6
4% 110
1.2% 1800
3.7% 1500
4.6% 2400
231 90Th

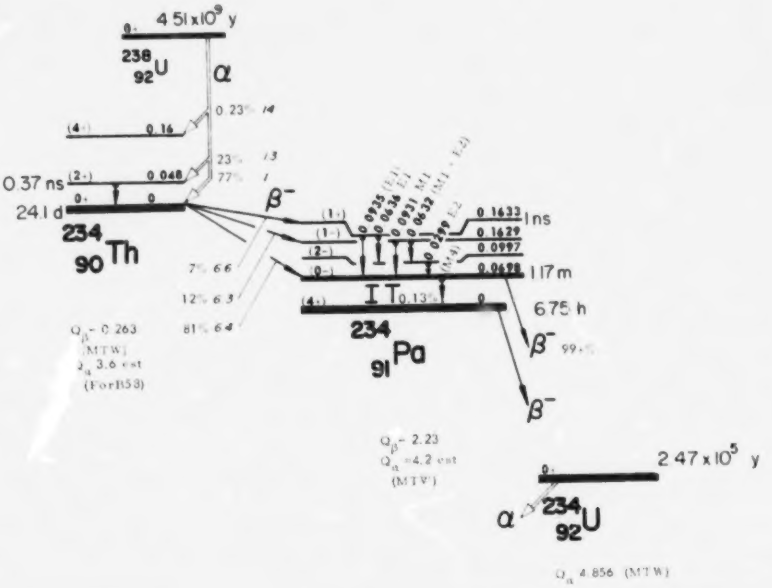
Q_{β^-} 0.381
Q_{α} 4.22 calc
(MTW)

^{235}U (7.1 × 10^8 y):

I: **7/2** atomic spect, paramag res; μ: **±0.35**, q: **±3.8** paramag res (LindgI64)

α: α_0 **4.597** (4.6%), α_{42} **4.556** (3.7%), α_{97} **4.502** (1.2%), α_{155} **4.445** ? (0.6%), α_{185} **4.415** (4%), α_{204} **4.396** (57%), α_{234} **4.366** (18%), α_{257} **4.344** ? (1.5%), α_{279} **4.323** (3%), α_{337} **4.266** (0.6%), α_{387} **4.216** (5.7%), α_{448} **4.157** (≈0.5%) mag spect, semicond spect (HydE64: compiled from PilR62, BaranS60a, SkiD61)
others (VorA60, VorA60a, PilR57, GhiA51b, WurE57, VesR52, ClarF57)

γ: γ_1 **0.110** (γ 2.5%), γ_2 **0.143** (γ 11%), γ_3 **0.163** (γ 5%), γ_4 **0.180** (γ 0.5%), γ_5 **0.185** (γ 54%), γ_6 **0.201** (γ 0.8%), γ_7 **0.204** (γ 5%) scint spect, γγ coinc (PilR62)
γ_1 **0.106**, γ_2 **0.143**, γ_5 **0.185** ($e_K/\gamma(\gamma_1+\gamma_2+\gamma_5)$ **0.10**, K/L ≈1.4), **0.192** (e_K/γ 2.0) scint spect, γα coinc (VorA60a)
others (JohaS56, FilI58)

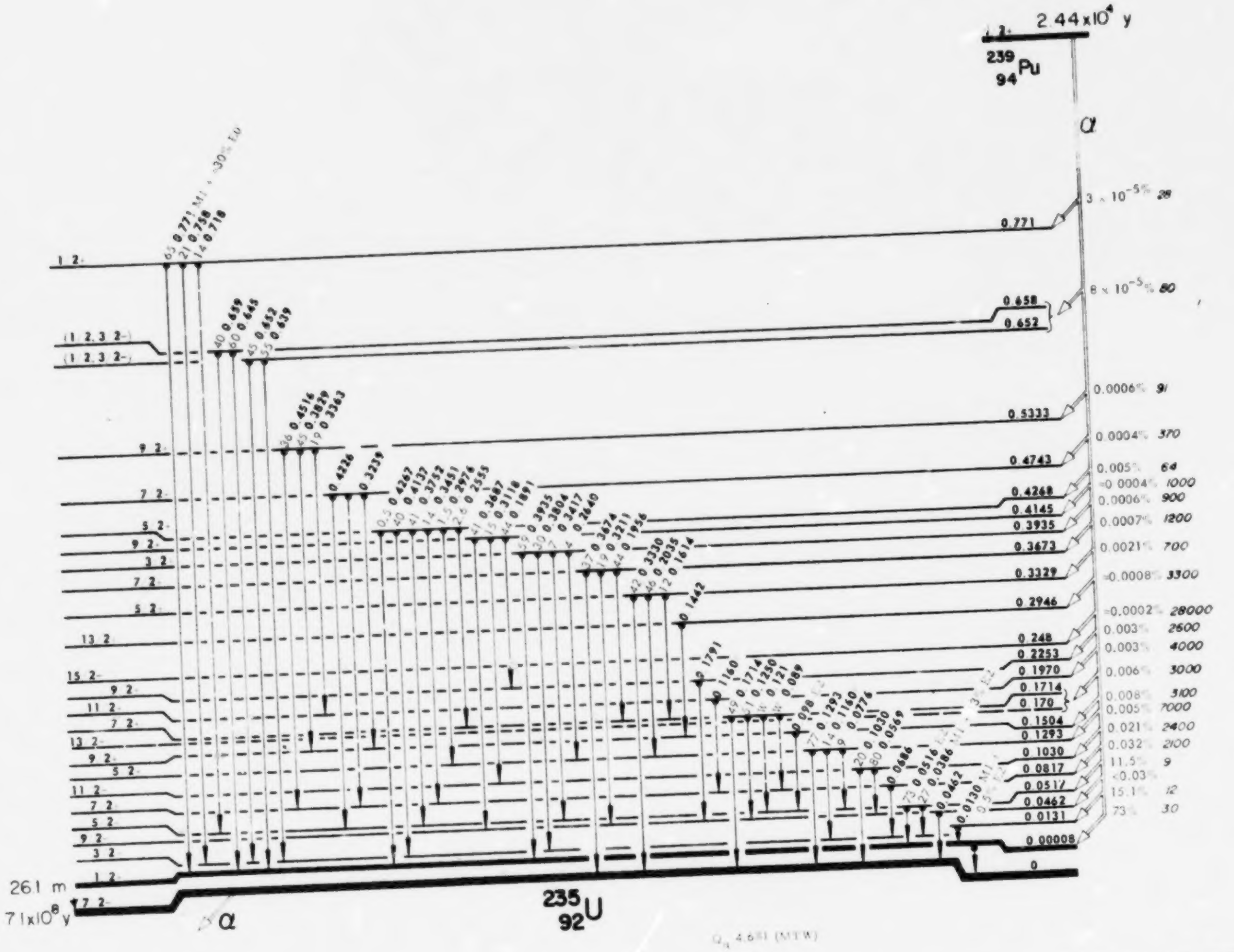


^{238}U (4.51 × 10^9 y):
α: $α_0$ **4.195** ion ch (VorA60a)
$α_0$ **4.200** ion ch (HarvB57)
$α_0$ (77%), $α_{48}$ (23%); $α_{160}$ (0.23%) ion ch (KocG59a)
others (BocB57, KomA58a, VorA59a, AldF47, ClarF57)
γ: **0.048** (e^- 23%) $αe^-$ coinc, range emuls (AlboG56, AlboG52, ZajB52)
others (DuaD52)
0.045 level of ^{238}U, $t_{1/2}$ 2.3 × 10^{-10} s, delay coinc (BellRE60)

^{234}Th (24.1 d):
$β^-$: **0.191** (65%), **0.100** (35%, coinc $γ_5 + γ_6$) βγ coinc, abs, mag spect (DHaaE55)
others (StokP52a, BradH46c, HeeM50, JnaS46, DHaaE55)
γ: $γ_1$ **0.0299** ($e^-/γ$ ~130, M_{II}/M_{III} 1), $γ_2$ **0.0632** ($L_I/L_{II}/L_{III}$ 2.5/1/1), $γ_3$ **0.0636** ($L_I/L_{II}/L_{III}$ 1/0.8/1, $I_γ(γ_2 + γ_3)$ 85, $e/γ$ 0.32), $γ_4$ **0.0698** (with ^{234m}Pa), $γ_5$ **0.0931** ($L_I/L_{II}/L_{III}$ 150/15/1), $γ_6$ **0.0935** ($I_γ(γ_5 + γ_6)$ 100, $e/γ$ 2.0) mag spect conv, scint spect (FouR62a)
others (OngP56a, JohaS54, AdaA62, BjoS63a, FouR59, FouR59a, FouR62, BriJ62, HeeM50, BradH46c, FouR65)
0.048 level of ^{234}Th, $t_{1/2}$ 3.7 × 10^{-10} s delay coinc (BellRE60)

^{234}Pa (6.75 h):
$β^-$: **1.35** (≈2%), **1.02** (7%), **0.73** (11%), **0.51** (66%), **0.23** (14%) mag spect (BjoS62)
1.13 (13%), **0.53** (27%), **0.32** (32%), **0.16** (28%) mag spect (OngP56a, OngP53, OngP55b)
γ: $γ_1$ **0.044** (L_{II} ≈34%, $L_{II}/L_{III}/M$ 3/3/2), $γ_2$ **0.100** (L_{II} ≈1%, $L_{II}/L_{III}/M$ 31/19/11), $γ_3$ **0.126** (γ≈24%, $e_{L_I}/γ$ ≈0.06), $γ_4$ **0.153** (γ 9%, $e_{L_{II}}/γ$ 0.7, $L_{II}/L_{III}/M$ 6.5/3.0/3.1), $γ_5$ **0.186** (γ ≈3%, K/L 6), $γ_6$ **0.197** (γ 4%, $e_L/γ$ ≈0.6), $γ_7$ **0.208** (? γ≈16%), $γ_8$ **0.224** (γ ≈2%, $e_K/γ$ ≈4), $γ_9$ **0.228** (γ 12%, $e_K/γ$ 1.2), $γ_{10}$ **0.287** (γ ≈10%, $e_K/γ$ ≈0.05), $γ_{11}$ **0.323** (? γ≈3%), $γ_{12}$ **0.355** (? γ≈6%), $γ_{13}$ **0.369** (γ 5.3%, $e_K/γ$ 0.4, K/L 4), $γ_{14}$ **0.565** (γ 15%, $e_K/γ$ 0.14, K/L/M 4/1/0.3), $γ_{15}$ **0.694** (K 0.4%), $γ_{16}$ **0.727** (K 0.7%), $γ_{17}$ **0.791** (γ ≤5%), $γ_{18}$ **0.804** (K 0.47%, K/L 4), $γ_{19}$ **0.822**, $γ_{20}$ **0.873**, $γ_{21}$ **0.875**, $γ_{22}$ **0.878** (K($γ_{20} + γ_{21} + γ_{22}$) 0.29%, K/L 5), $γ_{23}$ **0.920** , $γ_{24}$ **0.922** (K($γ_{23} + γ_{24}$) 0.26%), $γ_{25}$ **0.941** (K 0.12%, K/L 4), $γ_{26}$ **0.976** (K 0.03%, γ($γ_{19}$ – $γ_{26}$) 70%), $γ_{27}$ **1.020** (γ ≈8%), **1.13** (? γ 3%), **1.34** (? γ 2%), **1.41** (? γ 6%), **1.62** (? γ 3%), **1.85** (? γ 1%) mag spect conv, scint spect, γγ, $e^-γ$, βγ coinc (BjoS62)
$γ_1$ **0.0433** (L_{II}/L_{III} 1.1), $γ_2$ **0.0998** (L_{II}/L_{III} 1.4), $γ_3$ **0.1263**, $γ_4$ **0.1530** (L_{II}/L_{III} 1.9), $γ_5$ **0.1860**, $γ_6$ **0.1967** (?); $γ_8$ **0.2239**, **0.2267** (?), $γ_9$ **0.2273**, **0.2943** (?), $γ_{13}$ **0.3701** (?) mag spect conv (BriAC64)
$γ_1$ (L_{II}/L_{III} 1.0), $γ_2$ (L_{II}/L_{III} 1.3), $γ_4$ (L_{II}/L_{III} 2.1), $γ_8 + γ_9$ ($e_K/γ$ 0.6, K/L 6), $γ_{13}$ ($e_K/γ$ 0.24, K/L 3.5), $γ_{14}$ ($e_K/γ$ 0.1, K/L 3.5), $γ_{16}$ ($e_K/γ$ 0.012), $γ_{18}$ (K/L 2.4), $γ_{20} + γ_{21} + γ_{22}$ ($e_K/γ$ 0.01), $γ_{23} + γ_{24}$ ($e_K/γ$ 0.005), **1.24**, **1.43**, **1.68**, others, mag spect conv, scint spect (OngP56a, OngP53, OngP55b)
$γ_3$ ($I_γ$32), $γ_4$ ($I_γ$7), **0.23** ($I_γ$≈14), $γ_{10}$ (+ $γ_{12}$) ($I_γ$4), **0.46** ($I_γ$1.8), **0.69** ($I_γ$1.8), $γ_{17}$ ($I_γ$4), $γ_{20} + γ_{21}$ ($I_γ$9), $γ_{25}$ ($I_γ$1), $γ_{26} + γ_{27}$ ($I_γ$8) ($γ_3$ coinc $γ_2$, $γ_4$, 0.23γ, $γ_{10}$)
other γ rays reported, delay γγ coinc (HansP63a)
others (DLanP59, JohaS54, BouiG53a)
0.1633 level of ^{234}Pa, $t_{1/2}$ 6 × 10^{-10} s delay coinc (AboH64)
1.8 × 10^{-9} s delay coinc (FouR62a)

^{234m}Pa (1.17 m):
$β^-$: $β_1$ **2.29** (98%), $β_2$ **1.53** (coinc $γ_5$), $β_3$ **1.25** (coinc $γ_8$), mag spect, βγ coinc (BjoS63a)
others (StokP53a, HeeM50, DHaaE55, BradH45d)
γ (with $β^-$): $γ_1$ **0.0435** (e^- 2%, $L_{II}/L_{III}/M$ 0.9/1/1.3), $γ_2$ **0.236** (K 0.07%, $e_K/γ$ > 8, K/L 5), $γ_3$ **0.255** (γ 0.05%, $e_K/γ$ <0.1), $γ_4$ **0.746** (weak), $γ_5$ **0.765** (γ 0.36%, $e_K/γ$ 0.012), $γ_6$ **0.790** (weak), $γ_7$ **0.811** (K 0.4%, K/L/M 5/1/0.35), $γ_8$ **1.001** (γ 0.59%, $e_K/γ$ 0.01) mag spect conv, scint spect, $e^-γ$ coinc (BjoS63a)
γ (with IT): (0.070) (L 0.10%), γ's of ^{234}Pa mag spect conv, scint spect (BjoS63a)
others (OngP56a, DHaaE53, JohaS54, CrosW54, BradH43a, BradH45d, SchoH59)
γγ(θ): (WoodG60)



2.44x10⁴ y
1/2+
239 94 Pu
α
65 0.771 M1 + ~30% E2
21 0.758
14 0.718
40 0.659
50 0.645
45 0.652
55 0.639
56 0.4516
45 0.3829
19 0.3363
0.4226
0.3239
0.4267
0.4137
0.3752
0.3451
0.2976
0.2555
0.3687
0.3118
0.1891
0.3935
0.3804
0.3417
0.2640
0.3674
0.3211
0.1956
0.3330
0.2035
0.1614
0.1442
0.1791
0.1160
0.1714
0.1250
0.121
0.089
0.098
0.1293
0.1160
0.0776
0.1030
0.0569
0.0686
0.0516
0.0386
0.0462
0.0130 M1
1/2+
(1/2, 3/2-)
(1/2, 3/2-)
9/2
7/2
5/2
9/2
3/2
7/2
5/2
13/2
15/2
9/2
11/2
7/2
13/2
9/2
5/2
11/2
7/2
5/2
9/2
3/2
1/2
26.1 m
7/2-
7.1x10⁸ y
α
235 92 U
0.771
3 × 10⁻⁵% 28
0.658
0.652
8 × 10⁻⁵% 80
0.5333
0.0006% 91
0.4743
0.0004% 370
0.4268
0.005% 64
0.4145
≈0.0004% 1000
0.3935
0.0006% 900
0.3673
0.0007% 1200
0.3329
0.0021% 700
0.2946
≈0.0008% 3300
0.248
≈0.0002% 28000
0.2253
0.003% 2600
0.1970
0.003% 4000
0.1714
0.006% 3000
0.170
0.008% 3100
0.1504
0.005% 7000
0.1293
0.021% 2400
0.1030
0.032% 2100
0.0817
11.5% 9
0.0517
<0.03%
0.0462
15.1% 12
0.0131
73% 30
0.00008
0

Q_α 4.681 (MTW)

^{239}Pu (2.44 × 10^4 y):

I: **1/2** atomic beam, atomic spect (LindgI64), μ: +**0.200** atomic beam (FauJ65)

α: α_0 **5.156**, α_{13} **5.143**, α_{52} **5.105** mag spect (LeanC62)

α_0 **5.157** (73.3%), α_{13} **5.145** (15.1%), α_{46} (? <0.03%), α_{52} **5.107** (11.5%), α_{82} **5.078** (0.032%), α_{93} **5.066** (0.0009%), α_{103} **5.056** (0.021%), α_{129} **5.031** (0.005%), α_{150} **5.010** (0.008%), α_{160} **5.001** (0.0006%), α_{170} + α_{171} **4.988** (0.005%), α_{197} **4.963** (0.003%), α_{204} **4.957** (0.0005%), α_{225} **4.937** (0.003%), α_{248} **4.914** (0.0008%), α_{290} **4.873** (0.0007%), α_{295} **4.868**, α_{333} **4.830** (0.0015%), α_{367} **4.801** (0.0006%), α_{422} **4.743**, α_{427} **4.739** (α_{422} + α_{427} 0.0026%), α_{474} **4.695** (0.0004%), α_{533} **4.636** (0.0002%) mag spect (BaranS63)

α_{129} (0.005%), α_{171} (0.006%), α_{225} (0.003%), α_{248} (0.0002%), α_{295} (0.0008%), α_{333} (0.0021%), α_{367} (0.0007%), α_{393} (0.0006%), α_{414} ? (0.0004%), α_{427} (0.005%), α_{474} (0.0005%), α_{533} (0.0006%) αγ coinc (AhmI66)

α_{652} + α_{658} **4.52** (8 × 10^{-5}%), α_{771} **4.39** (3 × 10^{-5}%) αγ, αe^- coinc (BjoS63b)

others (DzhB61c, GoldiL55, NoviG57, AjzF56, AsaF52b, RosS50, HorsF65)

γ: γ_2 **0.0386** (I_γ150), γ_3 **0.0462** (I_γ16), γ_4 **0.0516** (I_γ410), γ_5 **0.0569** (I_γ16), γ_6 **0.0686** (I_γ14), γ_7 **0.0776** (I_γ11), γ_{10} **0.1030** (I_γ4), γ_{11} **0.1160** (I_γ18), γ_{13} **0.1250** (I_γ1.9), γ_{14} **0.1293** (I_γ100), γ_{15} **0.1417** (I_γ0.6), γ_{16} **0.1442** (I_γ5), γ_{17} **0.1460** (I_γ2.1), γ_{18} **0.1714** (I_γ1.8), γ_{19} **0.1791** (I_γ1.2), γ_{20} **0.1891** (I_γ1.5), γ_{21} **0.1956** (I_γ1.9), γ_{22} **0.2035** (I_γ9), γ_{23} **0.2555** (I_γ1.6), γ_{24} **0.2640** (I_γ0.6), γ_{25} **0.2976** (I_γ0.9), γ_{26} **0.3118** (I_γ0.5), γ_{27} **0.3211** (I_γ0.8), γ_{28} **0.3239** (I_γ0.9), γ_{29} **0.3330** (I_γ8), γ_{30} **0.3363** (I_γ1.8), γ_{31} **0.3417** (I_γ1.2), γ_{32} **0.3451** (I_γ8.7), γ_{33} **0.3674** (I_γ~1.6), γ_{34} **0.3687** (I_γ~1.4), γ_{35} **0.3752** (I_γ25), γ_{36} **0.3804** (I_γ5), γ_{37} **0.3829** (I_γ4), γ_{38} **0.3935** (I_γ10), γ_{39} **0.4137** (I_γ25), γ_{40} **0.4226** (I_γ2), γ_{41} **0.4267** ? (I_γ0.3), γ_{42} **0.4516** (I_γ3.4) semicond spect (AhmI66)

0.597 ? (γ 4 × 10^{-6}%), **0.617** ? (γ 6 × 10^{-6}%), **0.632** ? (γ 5 × 10^{-6}%), γ_{43} **0.639** (γ 1.7 × 10^{-5}%), γ_{44} **0.645** (γ 2 × 10^{-5}%), γ_{45} **0.652** (γ 1.3 × 10^{-5}%), γ_{46} **0.659** (γ 1.6 × 10^{-5}%, e/γ(γ_{43} + γ_{44} + γ_{45} + γ_{46}) <0.01), **0.674** ? (γ 1 × 10^{-6}%), **0.701** ? (γ 1 × 10^{-6}%), γ_{47} **0.705** (γ 6 × 10^{-6}%), γ_{48} **0.718** (γ 4 × 10^{-6}%), γ_{49} **0.758** (γ 6 × 10^{-6}%), γ_{50} **0.771** (γ 1.8 × 10^{-5}%, e/γ 0.5) semicond spect, γα, αe^- coinc (LedC64, BjoS63b)

γ_1 **0.0130** ($M_{I\text{-}II}$ 10%, $M_{I\text{-}II}$/M_{III} 2.8), γ_2 **0.0387** (L_I 2.1%, L_I:L_{II}:L_{III} 9:9:10), γ_4 **0.0517** (L 5%, L_{II}/L_{III} 1.1), **0.0659** ? (L_{III} 0.02%), γ_6 **0.071** (L 0.025%, L_{II}/L_{III} 4), **0.085** ($L_{I\text{-}II}$ 0.003%), γ_8 **0.089** ? (L_{III} 0.0007%), γ_9 **0.098** (L 0.010%, L_{II}/L_{III} 1.5), γ_{12} **0.121** ? (L_I 0.001%), mag spect conv (TretE58)

others (ShlK56a, AsaF57a, FreeM52, AlboG56, DunlD52, PetiG157, HorsF65)

0.286 level of ^{239}Pu: $t_{1/2}$ 1.1 × 10^{-9} s delay coinc (GrahR51a)

0.392 level of ^{239}Pu: $t_{1/2}$ 1.93 × 10^{-7} s delay coinc (EngeD55a)

^{235m}U (26.1 m):

γ: **0.000075** (75 eV) electrostatic analyzer (MicM57)
others (FreeM57)

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GLOSSARY

–A–

Absorbed Fraction: A term used in internal dosimetry. It is that fraction of the photon energy (emitted within a specified volume of material) which is absorbed by the volume. The absorbed fraction depends on the source distribution, the photon energy, and the size, shape, and composition of the volume.

Absorption: The process by which radiation imparts some or all of its energy to any material through which it passes. (*See* Compton Effect, Photoelectric Effect, and Pair Production.)

Self-Absorption: Absorption of radiation (emitted by radioactive atoms) by the material in which the atoms are located; in particular, the absorption of radiation within a sample being assayed.

Absorption Coefficient: Fractional decrease in the intensity of a beam of x or gamma radiation per unit thickness (linear absorption coefficient), per unit mass (mass absorption coefficient), or per atom (atomic absorption coefficient) of absorber, due to deposition of energy in the absorber. The total absorption coefficient is the sum of individual energy absorption processes (Compton effect, photoelectric effect, and pair production).

Atomic Absorption Coefficient: The linear absorption coefficient of a nuclide divided by the number of atoms per unit volume of the nuclide. It is equivalent to the nuclide's total cross section for the given radiation.

Compton Absorption Coefficient: That fractional decrease in the energy of a beam of x or gamma radiation due to the deposition of the energy to electrons produced by Compton effect in an absorber. (*See* Scattering, Compton.)

Linear Absorption Coefficient: A factor expressing the fraction of a beam of x or gamma radiation absorbed in unit thickness of material. In the expression $I = I_0 e^{-\mu x}$, I_0 is the initial intensity, I the intensity of the beam after passage through a thickness of the material x, and μ is the linear absorption coefficient.

Mass Absorption Coefficient: The linear absorption coefficient per cm. divided by the density of the absorber in grams per cu. cm. It is frequently expressed as μ/ρ, where μ is the linear absorption coefficient and ρ the absorber density.

Absorption Ratio, Differential: Ratio of concentration of a nuclide in a given organ or tissue to the concentration that would be obtained if the same administered quantity of this nuclide were uniformly distributed throughout the body.

Accelerator (Particle Accelerator): A device for imparting large kinetic energy to electrically charged particles such as electrons, protons, deuterons, and helium ions. Common types of particle accelerators are direct voltage accelerators (including Van de Graaff, Cockcroft-Walton, Dynamitron, resonant transformer, and insulating core transformer), cyclotrons (including synchrocyclotrons and isochronous cyclotrons), betatrons, and linear accelerators. (Individual accelerators listed alphabetically through glossary.)

Activation: The process of inducing radioactivity by irradiation.

Activity: The number of nuclear transformations occurring in a given quantity of material per unit time. (*See* Curie.)

Adsorption: The adhesion of one substance to the surface of another.

Alpha Particle: A charged particle emitted from the nucleus of an atom having a mass and charge equal in magnitude of a helium nucleus; i.e., two protons and two neutrons.

Alveoli: The terminal air sacs of the lungs.

Aluminum Equivalent: The thickness of aluminum affording the same attenuation, under specified conditions, as the material in question.

Ampere: The unit of current that, when flowing through each of two long parallel wires separated by one meter in free space, results in a force between the two wires (due to their magnetic fields) of 2×10^{-7} newtons for each meter of length.

Amplification: As related to radiation detection instruments, the process (gas, electronic, or both) by which ionization effects are magnified to a degree suitable for their measurement.

Amplifier, Linear: A pulse amplifier in which the output pulse height is proportional to an input pulse height for a given pulse shape up to a point at which the amplifier overloads.

Amplifier, Pulse: An amplifier, designed specifically to amplify the intermittent signals of a nuclear detector, incorporating appropriate pulse-shaping characteristics.

Analysis, Activation: A method of chemical analysis, especially for small traces of material, based on the detection of characteristic radiations following a nuclear bombardment.

Analysis, Feather: A technique for the determination of the range in aluminum of the beta particles of a radionuclide by comparison of the absorption curve with the absorption curve of a reference source, usually ^{210}Bi (range–501 mg/cm^2).

Analysis, Isotope Dilution: A method of chemical analysis for a component of a mixture, based on the addition to the mixture of a known amount of labeled component of known specific activity, followed by isolation of a quantity of the component and measurement of the specific activity of that sample.

Analyzer, Pulse Height: An electronic circuit which sorts and records the pulses according to height.

Anemia: Deficiency of blood as a whole, or deficiency in the number of the red corpuscles or of the hemoglobin.

Angstrom Unit: One angstrom unit equals 10^{-8} cm. (Symbol: Å)

Anion: Negatively charged ion.

Annihilation (Electron): An interaction between a positive and a negative electron in which they both disappear; their energy, including rest energy, being converted into electromagnetic radiation (called annihilation radiation).

Anode: Positive electrode; electrode to which negative ions are attracted.

Antimatter (Antiparticles): Matter in which the ordinary nuclear particles (neutrons, protons, electrons, etc.) are conceived of as being replaced by their corresponding antiparticles (antineutrons, antiprotons, positrons, etc.). An antihydrogen atom, for example, would consist of a negatively charged antiproton with an orbital positron. Normal matter and antimatter would mutually annihilate each other upon contact, being converted totally into energy. (*See* Matter.)

Atom: Smallest particle of an element which is capable of entering into a chemical reaction.

Atomic Mass: The mass of a neutral atom of a nuclide, usually expressed in terms of "atomic mass units." The "atomic mass unit" is one-twelfth the mass of one neutral atom of carbon-12; equivalent to 1.6604×10^{-24} gm. (Symbol: u).

Atomic Number: The number of protons in the nucleus of a neutral atom of a nuclide. The "effective atomic number" is calculated from the composition and atomic numbers of a compound or mixture. An element of this atomic number would interact with photons in the same way as the compound or mixture. (Symbol: Z).

Atomic Weight: The weighted mean of the masses of the neutral atoms of an element expressed in atomic mass units.

Attenuation: The process by which a beam of radiation is reduced in intensity when passing through some material. It is the combination of absorption and scattering processes and leads to a decrease in flux density of the beam when projected through matter.

Attenuation Coefficient, Compton: The fractional number of photons removed from a beam of radiation per unit thickness of a material through which it is passing as a result of Compton effect interactions.

Attenuation Coefficient, Linear: The fractional number of photons removed from a beam of radiation per unit thickness of a material through which it is passing due to all absorption and scattering processes.

Attenuation Coefficient, Pair Production: That fractional decrease in the intensity of a beam of ionizing radiation due to pair production in a medium through which it passes.

Attenuation Coefficient, Photoelectric Effect: That fractional decrease in the intensity of a beam of ionizing radiation due to photoelectric effect in a medium through which it is passing.

Attenuation Factor: A measure of the opacity of a layer of material for radiation traversing it; the ratio of the incident intensity to the transmitted intensity. It is equal to I_0/I, where I_0 and I are the intensities of the incident and emergent radiation, respectively. In the usual sense of exponential absorption ($I = I_0 e^{-\mu x}$), the attenuation factor is $e^{\mu x}$, where x is the thickness of the material and μ is the absorption coefficient.

Auger Effect: The emission of an electron from the extranuclear portion of an excited atom when the atom undergoes a transition to a less excited state.

Autofluoroscope: A device for visualizing the spatial distribution of a radionuclide within an organ or gland in the body. The autofluoroscope uses a multielement stationary detector composed of individual NaI(Tl) crystals. An image of the radionuclide distribution is obtained on a retention oscilloscope, or other readout devices.

Autoradiograph: Record of radiation from radioactive material in an object, made by placing the object in close proximity to a photographic emulsion.

Avalanche: The multiplicative process in which a single charged particle accelerated by a strong electric field produces additional charged particles through collision with neutral gas molecules. This cumulative increase of ions is also known as "Townsend ionization" or "Townsend avalanche."

Average Life (Mean Life): The average of the individual lives of all the atoms of a particular radioactive substance. It is 1.443 times the radioactive half-life.

Avogadro's Number (Avogadro Constant): Number of atoms in a gram atomic weight of any element; also the number of molecules in a gram molecular weight of any substance. It is numerically equal to 6.023×10^{23} on the unified mass scale. (Symbol: N_A).

–B–

Backscattering: The deflection of radiation by scattering processes through angles greater than 90 degrees, with respect to the original direction of motion.

Barn: Unit expressing the probability of a specific nuclear reaction, in terms of cross-sectional area. Numerically, it is 10^{-24} cm^2.

Barriers, Protective: Barriers of radiation-absorbing material, such as lead, concrete, and plaster, used to reduce radiation exposure.

Barriers, Primary Protective: Barriers sufficient to attenuate the useful beam to the required degree.

Barriers, Secondary Protective: Barriers sufficient to attenuate stray radiation to the required degree.

Baryon: One of a class of heavy elementary particles which includes neutrons, protons, and hyperons. (*See* Lepton, Meson.)

Beam: A unidirectional or approximately unidirectional flow of electromagnetic radiation or of particles.

Useful Beam (Radiology): Radiation which passes through the aperture, cone, or other collimating device of the source housing. Sometimes called "primary beam."

Beam Hole (Glory Hole): Hole through the shield, and usually through the reflector, of a reactor to permit the escape of a beam of radiation, in particular a beam of fast neutrons, for experimental purposes.

Beta Particle: Charged particle emitted from the nucleus of an atom, with a mass and charge equal in magnitude to that of the electron.

Betatron: A magnetic induction accelerator which makes use of a varying magnetic field to accelerate electrons. Electrons are injected into a toroidal vacuum chamber which is between the poles of an iron-core magnet. The rate of change of the magnet flux and magnetic field at the orbit radius are related to maintain a constant radius for the accelerating electrons.

Biologic Effectiveness of Radiation: (*See* Relative Biological Effectiveness.)

Blood Dyscrasia: Any persistent change from normal of one or more of the blood components.

Bone Marrow: Soft material which fills the cavity in most bones; it manufactures most of the formed elements of the blood.

Bone Seeker: Any compound or ion which migrates in the body preferentially into bone.

Brachytherapy: Therapy at short distances with beta or gamma radiation. Implantation or placement therapy with needles, inserts, or other such applications containing radioactive materials. Useful in the treatment of various diseases.

Bragg Gray Principle: The relationship between energy absorbed in a small gas-filled cavity in a medium to energy absorbed (in the medium) from ionizing radiation. The relationship is expressed as $E = W \times J \times S$; where E = energy/cc absorbed in the medium; W = average energy needed to produce an ion pair in the gas; J = number of ion pairs/cc formed in the gas; and S = ratio of the stopping power for secondary particles in the medium to that in the gas.

Branching: The occurrence of two or more modes by which a radionuclide can undergo radioactive decay. For example, RaC can undergo α or β^- decay, ^{64}Cu can undergo β^-, β^+, or electron capture decay. An individual atom of a nuclide exhibiting branching disintegrates by one mode only. The fraction disintegrating by a particular mode is the "branching fraction" for that mode. The "branching ratio" is the ratio of two specified branching fractions (also called multiple disintegration).

Breeder Reactor: (*See* Converter Reactor.)

Bremsstrahlung: Secondary photon radiation produced by deceleration of charged particles passing through matter.

British Thermal Unit (BTU): The quantity of heat required to increase the temperature of one pound of water one degree Fahrenheit at atmospheric pressure; approximately 252 gram-calories.

Buildup Factor: The ratio of the intensity of x or gamma radiation (both primary and scattered) at a point in an absorbing medium to the intensity of only the primary radiation. This factor has particular application for "broad beam" attenuation. "Intensity" may refer to energy flux, dose, or energy absorption.

Burial Ground (Graveyard): A place for burying unwanted radioactive objects to prevent escape of their radiations, the earth or water acting as a shield. Such objects must be placed in watertight, noncorrodible containers so the radioactive material cannot leach out and invade underground water supplies.

–C–

Calibration: Determination of variation from standard, or accuracy, of a measuring instrument to ascertain necessary correction factors.

Calorie (Gram-Calorie): Amount of heat necessary to raise the temperature of one gram of water 1° C (from 14.5 to 15.5° C). (Abbreviation: cal.)

Cancer: Any malignant neoplasm. (Popular usage.)

Capillary: A small, thin-walled blood vessel connecting an artery with a vein.

Capture, Electron: A mode of radioactive decay involving the capture of an orbital electron by its nucleus. Capture from a particular electron shell is designated as "K-electron capture," "L-electron capture," etc.

Capture, K-Electron: Electron capture from the K shell by the nucleus of the atom. Also loosely used to designate any orbital electron capture process.

Capture, Radiative: The process by which a nucleus captures an incident particle and loses its excitation energy immediately by the emission of gamma radiation.

Capture, Resonance: An inelastic nuclear collision occurring when the nucleus exhibits a strong tendency to capture incident particles or photons of particular energies.

Carcinogenic: Capable of producing cancer.

Carcinoma: Malignant neoplasm composed of epithelial cells, regardless of their derivation.

Carrier: A quantity of non-radioactive or non-labeled material of the same chemical composition as its corresponding radioactive or labeled counterpart. When mixed with the corresponding radioactive labeled material, so as to form a chemically inseparable mixture, the carrier permits chemical (and some physical) manipulation of the mixture with less label or radioactivity loss than would be true for the undiluted label or radioactivity.

Carrier, Hold-Back: The inactive isotope or isotopes of a radioactive element, or an element of similar properties, or some reagent which may be used to diminish the amount of the radionuclide coprecipitated or absorbed in a chemical reaction.

Carrier-Free: An adjective applied to one or more radioactive isotopes of an element in minute quantity, essentially undiluted with stable isotope carrier.

Catalyst: A substance which alters the velocity of a chemical reaction (positive catalysts increase velocity) yet may be recovered practically unchanged after the reaction has occurred.

Cataract: A clouding of the crystalline lens of the eye which obstructs the passage of light.

Cathode: Negative electrode; electrode to which positive ions are attracted.

Cation: Positively charged ion.

Cell: (Biological) The fundamental unit of structure and function in organisms.

Cells, Somatic: Body cells, usually with two sets of chromosomes, as opposed to germ cells, which have only one set.

Chamber, Cloud: A device for observing the paths of ionizing particles. It is based on the principle that supersaturated vapor condenses more readily on ions than on neutral molecules.

Chamber, Ionization: An instrument designed to measure a quantity of ionizing radiation in terms of the charge of electricity associated with ions produced within a defined volume.

Air-Wall Ionization Chamber: Ionization chamber in which the materials of the wall and electrodes are so selected as to produce ionization essentially equivalent to that in a free-air ionization chamber. This is possible only over limited ranges of photon energies. Such a chamber is more appropriately termed an "air-equivalent ionization chamber."

Extrapolation Ionization Chamber: An ionization chamber with electrodes whose spacing can be adjusted and accurately determined to permit extrapolation of its reading to zero chamber volume.

Free-Air Ionization Chamber: An ionization chamber in which a delimited beam of radiation passes between the electrodes without striking them or other internal parts of the equipment. The electric field is maintained perpendicular to the electrodes in the collecting region. As a result, the ionized volume can be accurately determined from the dimensions of the collecting electrode and the limiting diaphragm. This is the basic standard instrument for x-ray dosimetry within the range of 5 to 1400 kVp.

Thimble Ionization Chamber: A small cylindrical or spherical ionization chamber, usually with walls of organic material.

Tissue-Equivalent Ionization Chamber: An ionization chamber in which the material of the walls, electrodes, and gas are so selected as to produce ionization essentially equivalent to that characteristic of the tissue under consideration. In some cases it is sufficient to have only tissue equivalent walls, and the gas may be air, provided the air volume is negligible. The essential point in this case is that the contribution to the ionization in the air made by ionizing particles originating in the air is negligible, compared to that produced by ionizing particles characteristic of the wall material.

Chamber, Pocket: A small, pocket-sized ionization chamber used for monitoring radiation exposure of personnel. Before use, it is given a charge and the amount of discharge is a measure of the radiation exposure.

Charge: The fissionable material or fuel placed in a reactor to produce a chain reaction. To assemble the charge in a reactor.

Charge, Space: The electric charge carried by a cloud or stream of electrons or ions in a vacuum or a region of low gas pressure, when the charge is sufficient to produce local changes in the potential distribution. It is of importance in thermionic tubes, photoelectric cells, ion accelerators, etc.

Chemical (Isotopic) Exchange: A process in which atoms (isotopes) of the same element in two different molecules exchange places.

Cherenkov Radiation: Blue light emitted when a charged particle moves in a transparent medium with a speed greater than that of light in the same medium.

Circuit, Anticoincidence: A circuit with two input terminals which delivers an output pulse if one input terminal receives a pulse, but delivers no output pulse if pulses are received by both input terminals simultaneously or within an assignable time interval.

Circuit, Coincidence: An electronic circuit that produces a usable output pulse only when each of two or more input circuits receives pulses simultaneously or within an assignable time interval.

Circuit, Integrating: An electronic circuit which records the total number of ions or events collected for a given time from which an average value for the number of ions or events per unit time can be found.

Circular Mil: An area equal to the area contained in a circle of one mil in diameter or 7.854×10^{-7} square inch.

Cladding (Clad): An external layer of material applied directly to nuclear fuel or other material to provide protection from a chemically reactive environment, to provide containment of radioactive products produced during the irradiation of the composite, or to provide structural support.

Clinical: Pertaining to the observed symptoms and cause of disease.

Cockcroft-Walton Accelerator: A device for accelerating charged particles by application of a very high direct-current voltage to a stream of ions in a straight insulated tube. The high voltage is obtained through a number of rectifiers and capacitors arranged in a series-coupled-voltage multiplier circuit.

Coincidence: The occurrence of counts in two or more detectors simultaneously or within an assignable time interval. A *true coincidence* is one that is due to the incidence of a single particle or of several genetically related particles. An *accidental, chance*, or *random* coincidence is one that is due to the accidental occurrence of unrelated counts in the separate detectors. An *anticoincidence* is the occurrence of a count in a specified detector unaccompanied simultaneously or within an assignable time interval by a count in other specified detectors. A *delayed coincidence* is the occurrence of a count in one detector at a short, but measurable, time after a count in another detector. The two counts are due to a genetically related occurrence, such as successive events in the same nucleus.

Collimator: A device for confining the elements of a beam within an assigned solid angle.

Collision: Encounter between two subatomic particles (including photons) which changes the existing momentum and energy conditions. The products of the collision need not be the same as the initial systems.

Elastic Collision: A collision in which there is no change either in the internal energy of each participating system or in the sum of their kinetic energies of translation.

Inelastic Collision: A collision in which there are changes both in the internal energy of one or more of the colliding systems and in the sums of the kinetic energies of translation before and after the collision.

Column, Thermal: A column or large body of moderator, such as graphite, extending away from the active section of a nuclear reactor to provide near its other end (for experimental purposes) a flux of thermal neutrons of high cadmium ratio; i.e., containing few virgin and epithermal neutrons.

Compound: A distinct substance formed by a union of two or more ingredients in definite proportions by weight.

Compton Effect: An attenuation process observed for x or gamma radiation in which an incident photon interacts with an orbital electron of an atom to produce a recoil electron and a scattered photon of energy less than the incident photon.

Condenser R-Meter: An instrument consisting of an "air-wall" ionization chamber together with auxiliary equipment for charging and measuring its voltage. It is used as an integrating instrument for measuring the exposure of x or gamma radiation in roentgens, (R). (*See* Chamber, Ionization.)

Contamination, Radioactive: Deposition of radioactive material in any place where it is not desired, particularly where its presence may be harmful. The harm may be in vitiating an experiment or a procedure, or in actually being a source of danger to personnel.

Control: The purposeful variation of the reactivity of a reactor. "Absorber control" is obtained by varying the amount of neutron absorbers within the reactor. "Configuration control" is obtained by changing the geometry of the reactor.

Control System: A coordinated group of components designed to exert a directing influence on other components. A system of apparatus for controlling the rate of reaction in a nuclear reactor. The term may refer to all apparatus provided for this purpose or to one of several essentially independent arrangements, such as a regulating system and safety system. A reaction may be controlled automatically by a servo system that adjusts the control elements to maintain the flux level near a desired value. A reactor may have a tendency toward stability because of self-regulation, but this quality of stability ordinarily is not considered part of the control system.

Controlled Area: A defined area in which the occupational exposure of personnel (to radiation) is under the supervision of the Radiation Protection Supervisor.

Conversion (Reactor Technology): Nuclear transformation of a fertile substance into a fissile substance.

Conversion Ratio: The ratio of the number of fissile nuclei produced by conversion to the number of fissile nuclei destroyed. The term can refer to an instant of time or to a period of time.

Converter Reactor: The difference between "converter" and "breeder" reactor is that a converter produces fissile atoms from fertile atoms, but has a conversion ratio less than one. A breeder reactor has a conversion ratio greater than one and therefore produces more fissile atoms than it consumes.

Coolant: A substance, usually liquid or gas, used for cooling any part of a reactor in which heat is generated. Such parts include not only the core but also the reflector, shield, and other elements that may be heated by absorption of radiation.

Core: In a nuclear reactor, the region containing the fissionable material. The body of fuel or moderator and fuel in a nuclear reactor. It does not include the fuel outside the active section in a circulating reactor. Identical with active lattices in a reactor. In a heterogeneous reactor, the region containing fuel-bearing cells.

Corpuscle: A blood cell.

Corpuscular Emission, Associated: The full complement of secondary charged particles (usually limited to electrons) associated with an x-ray or gamma-ray beam in its passage through air. The full complement of electrons is obtained after the radiation has traversed sufficient air to bring about equilibrium between the primary photons and secondary electrons. Electronic equilibrium with the secondary photons is intentionally excluded.

Cosmic Rays: High-energy particulate and electromagnetic radiations which originate outside the earth's atmosphere.

Coulomb: Unit of electrical charge in the MKSA system of units. A quantity of charge equal to one ampere second.

Count (Radiation Measurements): The external indication of a device designed to enumerate ionizing events. It may refer to a single detected event or to the total number registered in a given period of time. The term often is erroneously used to designate a disintegration, ionizing event, or voltage pulse.

> **Spurious Count**: In a radiation counting device, a count caused by any agency other than radiation.

Counter, Gas Flow: A device in which an appropriate atmosphere is maintained in the counter tube by allowing a suitable gas to flow slowly through the sensitive volume.

Counter, Geiger-Mueller: Highly sensitive, gas-filled radiation-measuring device. It operates at voltages sufficiently high to produce avalanche ionization.

Counter, Proportional: Gas-filled radiation detection device; the pulse produced is proportional to the number of ions formed in the gas by the primary ionizing particle.

Counter, Scintillation: The combination of phosphor, photomultiplier tube, and associated circuits for counting light emissions produced in the phosphors.

Counting, Coincidence: A technique in which particular types of events are distinguished from background events by coincidence circuits which register coincidences caused by the type of events under consideration.

Counting Ratemeter: An instrument which gives a continuous indication of the average rate of ionizing events.

Critical: Capable of sustaining (at a constant level) a chain reaction. "Prompt critical" means sustaining a chain reaction without the aid of delayed neutrons.

Critical Size: Any one of a set of physical dimensions of the core and reflector of a nuclear reactor maintaining a critical chain reaction, the material and structure of the core and the reflector having been specified.

Cross Section, Capture: The probability that a nucleus will capture an incident particle. The unit of cross section is commonly the barn (10^{-24} cm^2).

Cross Section, Nuclear: The probability that a certain reaction between a nucleus and an incident particle or photon will occur. It is expressed as the effective "area" the nucleus presents for the reaction. "Macroscopic cross section" refers to the cross section per unit volume (preferably) or per unit mass. "Microscopic cross section" is the cross section of one atom or molecule. (*See* Barn, and Cross Section, Capture.)

Curie: The special unit of activity. One curie equals 3.700×10^{10} nuclear transformations per second. (Abbreviated Ci.) Several fractions of the curie are in common usage.

> **Microcurie**: One-millionth of a curie (3.7×10^4 disintegrations per sec.). Abbreviated μCi.
>
> **Millicurie**: One-thousandth of a curie (3.7×10^7 disintegrations per second). Abbreviated mCi.
>
> **Picocurie**: One-millionth of a microcurie (3.7×10^{-2} distintegrations per second or 2.22 disintegrations per minute). Abbreviated pCi; replaces the term μμc.

Cyclotron: A particle accelerator which uses a magnetic field to confine a positive ion beam to a plane while an alternating electric field accelerates the ions in a spiral path. An RF voltage is applied between one or two hollow semicircular electrodes called "dees" at the frequency at which the ions rotate (which is constant in the conventional cyclotron). As the voltage between the dees alternates, particles are accelerated as they enter and leave the dees.

–D–

Daughter: Synonym for decay product.

Decay, Radioactive: Disintegration of the nucleus of an unstable nuclide by spontaneous emission of charged particles and/or photons.

Decay Constant: The fraction of the number of atoms of a radioactive nuclide which decay in unit time. Symbol: λ. (*See* Disintegration Constant.)

Decay Curve: A curve showing the relative amount of radioactive substance remaining after any time interval. (*See* Disintegration Constant.)

Decay Product: A nuclide resulting from the radioactive disintegration of a radionuclide, formed either directly or as the result of successive transformations in a radioactive series. A decay product may be either radioactive or stable.

Decontamination Factor: The ratio of the amount of undesired radioactive material initially present to the amount remaining after a suitable processing step has been completed. Decontamination factors may refer to the reduction of some particular type of radiation, or to the gross measurable radioactivity.

Delayed Neutron: Neutrons emitted by excited nuclei formed in a radioactive process; so-called because they are emitted an appreciable time after fission. They are important in the control of nuclear reactors.

Delta Ray: Any secondary ionizing particle ejected by recoil when a primary ionizing particle passes through matter.

Densitometer: Instrument utilizing a photocell to determine the degree of darkening of developed photographic film.

Density (Photographic): Used to denote the degree of darkening of photographic film. Logarithm of opacity of exposed and processed film. Opacity is the reciprocal of transmission; transmission is the ratio of transmitted to incident intensity.

Depletion: Reduction of the concentration of one or more specified isotopes in a material or in one of its constituents.

Depolymerization: The breaking down of an organic compound into two or more molecules of less complex structure.

Detector, Radiation: Any device for converting radiant energy to a form more suitable for observation. An instrument used to determine the presence, and sometimes the amount, of radiation.

Deuterium: A heavy isotope of hydrogen with one proton and one neutron in the nucleus. (Symbol: ${}^2_1$H or D).

Deuteron: Nucleus of a deuterium atom.

Direct Voltage Accelerator (Potential Drop Accelerator): An accelerator which uses a constant voltage to accelerate particles and is typically constructed with an ion or electron source inside a "terminal," which operates at a very high voltage with respect to the target area, which is at ground potential. Usually named according to the type of power supply used.

Discriminator, Pulse Height: A circuit designed to select and pass voltage pulses of a certain specified amplitude.

Disintegration Constant: The fraction of the number of atoms of a radioactive nuclide which decay in unit time; λ in the equation $N = N_0e^{-\lambda t}$, where N_0 is the initial number of atoms present, and N is the number of atoms present after some time, t.

Disintegration, Nuclear: A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus. When numbers of nuclei are involved, the process is characterized by a definite half-life.

Dollar (Reactor Technology): A special unit of reactivity; equal to that amount of reactivity required to make a reactor critical on prompt neutrons only, and therefore equal to the effective delayed neutron fraction for that reactor.

Doppler Broadening: In spectroscopy, the observed broadening of a spectral line resulting from the thermal motion of the molecules, atoms, or nuclei. In reactor technology, it is the observed broadening of the energy width of a cross section resonance resulting from the thermal motion of the target particles.

Doppler Effect: The change in the observed wave length of a radiation which results from the motion of its source relative to the observer.

Dose: A general form denoting the quantity of radiation or energy absorbed. For special purposes it must be appropriately qualified. If unqualified, it refers to absorbed dose.

Absorbed Dose: The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. The unit of absorbed dose is the rad. One rad equals 100 ergs per gram. (*See* Rad.)

Cumulative Dose (Radiation): The total dose resulting from repeated exposures to radiation.

Depth Dose: The radiation dose delivered at a particular depth beneath the surface of the body. It is usually expressed as a percentage of surface dose.

Dose Equivalent (DE): A quantity used in radiation protection. It expresses all radiations on a common scale for calculating the effective absorbed dose. It is defined as the product of the absorbed dose in rads and certain modifying factors. (The unit of dose equivalent is the rem.)

Exit Dose: Dose of radiation at surface of body opposite to that on which the beam is incident.

Integral Dose (Volume Dose): A measure of the total energy absorbed by a patient or object during exposure to radiation. (*See* Gram-Rad.)

Maximum Permissible Dose Equivalent (MPD): The greatest dose equivalent that a person or specified part thereof shall be allowed to receive in a given period of time.

Median Lethal Dose (MLD): Dose of radiation required to kill, within a specified period, 50 percent of the individuals in a large group of animals or organisms. Also called the LD_{50}.

Percentage Depth Dose: Dose of radiation delivered at a specified depth in tissue, expressed as a percentage of the skin dose.

Permissible Dose: The dose of radiation which may be received by an individual within a specified period with expectation of no significantly harmful result.

Skin Dose (Radiology): Absorbed dose at center of irradiation field on skin. It is the sum of the dose in air and scatter from body parts.

Threshold Dose: The minimum absorbed dose that will produce a detectable degree of any given effect.

Tissue Dose: Absorbed dose received by tissue in the region of interest, expressed in rads. (*See* Dose and Rad.)

Dose, Fractionation: A method of administering radiation, in which relatively small doses are given daily or at longer intervals.

Dose, Protraction: A method of administering radiation by delivering it continuously over a relatively long period at a low dose rate.

Dose Meter, Integrating: Ionization chamber and measuring system designed for determining total radiation administered during an exposure. In medical radiology the chamber is usually designed to be placed on the patient's skin. A device may be included to terminate the exposure when it has reached a desired value.

Dose Rate: Absorbed dose delivered per unit time.

Dose Ratemeter: Any instrument which measures radiation dose rate.

Dosimeter: Instrument to detect and measure accumulated radiation exposure. In common usage, a pencil-size ionization chamber with a self-reading electrometer, used for personnel monitoring.

Dosimetry, Photographic: Determination of cumulative radiation dose with photographic film and density measurement.

Dynamitron: A particle accelerator using a voltage multiplying circuit with the stages driven by high voltage capacitors in parallel. A radiofrequency power source is used to charge the capacitors.

Dyne: The unit of force which, when acting upon a mass of one gram, will produce an acceleration of one centimeter per second per second.

–E–

Efficiency (Counters): A measure of the probability that a count will be recorded when radiation is incident on a detector. Usage varies considerably, so it is well to ascertain which factors (window transmission, sensitive volume, energy dependence, etc.) are included in a given case.

Electrode: A conductor used to establish electrical contact with a nonmetallic part of a circuit.

Electrometer: Electrostatic instrument for measuring the difference in potential between two points. Used to measure change of electric potential of charged electrodes resulting from ionization produced by radiation.

Electromotive Force: Potential difference across electrodes tending to produce an electric current.

Electron: A stable elementary particle having an electric charge equal to $\pm 1.60210 \times 10^{-19}$ C. and a rest mass equal to 9.1091×10^{-31} kg.

Secondary Electron: An electron ejected from an atom, molecule, or surface as a result of an interaction with a charged particle or photon.

Valence Electron: Electron which is gained, lost, or shared in a chemical reaction.

Electron Volt: A unit of energy equivalent to the energy gained by an electron in passing through a potential difference of one volt. Larger multiple units of the electron volt are frequently used: *keV* for thousand or *kilo electron volts; MeV* for million or *mega electron volts.* (Abbreviated: eV, 1 eV = 1.6×10^{-12} erg.)

Electroscope: Instrument for detecting the presence of electric charges by the deflection of charged bodies.

Electrostatic Field: The region surrounding an electric charge in which another electric charge experiences a force.

Electrostatic Unit of Charge: (*See* Statcoulomb.)

Element: A category of atoms all of the same atomic number.

Emulsion, Nuclear: A photographic emulsion specially designed to permit observation of the individual tracks of ionizing particles.

End Product: The stable nuclide that is the final member of a radioactive series.

Energy: Capacity for doing work. "Potential energy" is the energy inherent in a mass because of its spatial relation to other masses. "Kinetic energy" is the energy possessed by a mass because of its motion; MKSA units: kg-m^2/sec^2 or joules.

Binding Energy: The energy represented by the difference in mass between the sum of the component parts and the actual mass of the nucleus.

Excitation Energy: The energy required to change a system from its ground state to an excited state. Each different excited state has a different excitation energy.

Ionizing Energy: The average energy lost by ionizing radiation in producing an ion pair in a gas. For air, it is about 33.73 eV.

Radiant Energy: The energy of electromagnetic radiation, such as radio waves, visible light, x and gamma rays.

Reaction Energy (Nuclear): In the disintegration of a nucleus, it is equal to the sum of the kinetic or radiant energies of the reactants minus the sum of the kinetic or radiant energies of the products. If any product of a specified reaction is in an excited nuclear state, the energy of subsequently emitted gamma radiation is not included in the sum. The "ground-state nuclear reaction energy" is the reaction energy when all reactant and product nuclei are in their ground states. (Symbol: Q_o).

Energy Dependence: The characteristic response of a radiation detector to a given range of radiation energies or wave lengths compared with the response of a standard free-air chamber.

Energy Fluence: The sum of the energies, exclusive of rest energies, of all particles passing through a unit cross-sectional area.

Energy Flux Density (energy fluence rate): The sum of the energies, exclusive of rest energies, of all particles passing through a unit cross-sectional area per unit time. (Energy fluence per unit of time.)

Enriched Material: (1) Material in which the relative amount of one or more isotopes of a constituent has been increased. (2) Uranium in which the abundance of the ^{235}U isotope is increased above normal.

Enzyme: A biological catalyst of great specificity for a particular substance (substrate) or a particular group of closely related substances which generally activates or accelerates a biochemical reaction.

Epidermis: The outermost layer of cells of the skin.

Epilation (Depilation): The temporary or permanent removal or loss of hair.

Epithelium: A term applied to cells that line all canals and surfaces having communication with external air; also, cells specialized for secretion in certain glands as the liver, kidneys, etc.

Equilibrium, Radioactive: In a radioactive series, the state which prevails when the ratios between the amounts of successive members of the series remains constant.

Secular Equilibrium: If a parent element has a very much longer half-life than the daughters (so there is no appreciable change in its amount in the time interval required for later products to attain equilibrium) then, after equilibrium is reached, equal numbers of atoms of all members of the series disintegrate in unit time. This condition is never actually attained, but is essentially established in such a case as radium and its series to Radium D. The half-life of radium is about 1,600 years; of radon, approximately 3.82 days, and of each of the subsequent members, a few minutes. After about a month, essentially the equilibrium amount of radon is present; then (and for a long time) all members of the series disintegrate the same number of atoms per unit time.

Transient Equilibrium: If the half-life of the parent is short enough so the quantity present decreases appreciably during the period under consideration, but is still longer than that of successive members of the series, a stage of equilibrium will be reached after which all members of the series decrease in amount exponentially with the period of the parent. An example of this is radon (half-life of approximately 3.82 days) and successive members of the series to Radium D.

Erg: Unit of work done by a force of one dyne acting through a distance of one cm. Unit of energy which can exert a force of one dyne through a distance of one cm; cgs units: dyne-cm or gm-cm^2/sec^2.

Error, Statistical: Errors in counting due to the random time-distributions of disintegrations.

Erythema: An abnormal redness of the skin due to distension of the capillaries with blood. It can be caused by many different agents–heat, drugs, ultraviolet rays, ionizing radiation.

Erythrocyte: A red blood corpuscle.

Eugenics: The science which deals with the influences that improve the hereditary qualities of a race or breed.

Excitation: The addition of energy to a system, thereby transferring it from its ground state to an excited state. Excitation of a nucleus, an atom, or a molecule can result from absorption of photons or from inelastic collisions with other particles.

Exoergic: That which liberates energy.

Exposure: A measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of the air in the volume element. The special unit of exposure is the roentgen.

Acute Exposure: Radiation exposure of short duration.

Chronic Exposure: Radiation exposure of long duration by fractionation or protraction. *(See* Dose, Fractionation and Dose, Protraction.)

–F–

Fallout: Radioactive debris from a nuclear detonation, which is airborne or has been deposited on the earth. Special forms of fallout are "Dry Fallout," "Rainout," and "Snowout."

Fertile: Of a nuclide, capable of being transformed, directly or indirectly, into a fissile nuclide by neutron capture. Of a material, containing one or more fertile nuclides.

Film Badge: A pack of photographic film which measures radiation exposure for personnel monitoring. The badge may contain two or three films of differing sensitivity and filters to shield parts of the film from certain types of radiation.

Film Ring: A film badge in the form of a finger ring.

Filter (Radiology): Primary–A sheet of material, usually metal, placed in a beam of radiation to absorb preferentially the less penetrating components. Secondary–A sheet of material of low atomic number (relative to the primary filter) placed in the filtered beam of radiation to remove characteristic radiation produced by the primary filter.

Filtration, Inherent (x rays): The filter permanently in the useful beam; it includes the window of the x-ray tube and any permanent tube or source enclosure.

Fissile: Of a nuclide, capable of undergoing fission by interaction with slow neutrons.

Fission, Nuclear: A nuclear transformation characterized by the splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy.

Fission Products: Elements or compounds resulting from fission.

Fission Yield: The percentage of fissions leading to a particular nuclide.

Fissionable: Of a nuclide, capable of undergoing fission by any process.

Fluence: The number of particles passing through a unit cross-sectional area.

Fluorescence: The emission of radiation of particular wavelengths by a substance as a result of absorption of radiation of shorter wavelength. This emission occurs essentially only during the irradiation.

Fluorescent Screen: A sheet of material coated with a substance (such as calcium tungstate or zinc sulfide) which will emit visible light when irradiated with ionizing radiation.

Fluorography (Photofluorography): Photography of image produced on fluorescent screen by x or gamma radiation.

Fluoroscope: A fluorescent screen, suitably mounted with respect to an x-ray tube for ease of observation and protection, used for indirect visualization (by x rays) of internal organs in the body or internal structures in apparatus or in masses of material.

Flux Density (fluence rate): The number of particles passing through a unit cross-sectional area per unit of time. (Fluence per unit of time.)

Flux, Neutron: A term used to express the intensity of neutron radiation. The number of neutrons passing through a unit area in unit time. For neutrons of a given energy, the product of neutron density with speed.

Focal Spot (x rays): The part of the target of the x-ray tube struck by the main electron stream.

Frequency: Number of cycles, revolutions, or vibrations completed in a unit of time. (*See* Hertz.)

Fuel: Fissionable material of reasonably long life, used or usable in producing energy in a nuclear reactor. The term frequently is applied to a mixture, such as natural uranium, in which only part of the atoms are fissionable, if it can maintain a self-sustaining chain reaction under the proper conditions.

Fuel Cycle: The sequence of steps, such as utilization, reprocessing, and refabrication, through which nuclear fuel passes.

Fusion, Nuclear: Act of coalescing two or more atomic nuclei. (*See* Reaction, Thermonuclear.)

–G–

Gamete: Either of the two germ cells (sperm or ovum).

Gamma, Prompt: Gamma radiation emitted at the time of fission of a nucleus.

Gamma Ray: Short wavelength electromagnetic radiation of nuclear origin (range of energy from 10 keV to 9 MeV) emitted from the nucleus.

Gas Amplification: As applied to gas ionization radiation detecting instruments, the ratio of the charge collected to the charge produced by the initial ionizing event.

Geiger Region: In an ionization radiation detector, the operating voltage interval in which the charge collected per ionizing event is essentially independent of the number of primary ions produced in the initial ionizing event.

Geiger Threshold: The lowest voltage applied to a counter tube for which the number of pulses produced in the counter tube is essentially the same, regardless of a limited voltage increase.

Gene: Fundamental unit of inheritance which determines and controls hereditarily transmissible characteristics. Genes are arranged linearly at definite loci on chromosomes.

Generator ("Cow"): A device in which a daughter radionuclide is eluted from an ion exchange column containing a parent radionuclide long-lived compared to the daughter.

Genetic Effect of Radiation: Inheritable change, chiefly mutations, produced by the absorption of ionizing radiations. On the basis of present knowledge these effects are purely additive; there is no recovery.

Genetics: The branch of biology dealing with the phenomena of heredity and variation.

Genotype: The fundamental hereditary (genetic) constitution of an organism.

Geometry Factor: The fraction of the total solid angle about the source of radiation that is subtended by the face of the sensitive volume of a detector.

Geometry, Good: In nuclear physics measurements, an arrangement of source and detecting equipment such that the use of finite source size and finite detector aperture introduces little error.

Geometry, Poor: In a nuclear experiment, an arrangement in which the angular aperture between the source and detector is large, introducing into the measurement a comparative large uncertainty for which a correction may be necessary.

Germ Cells: The cells of an organism whose function is reproduction.

Gonad: A gamete-producing organ in animals; testis or ovary.

Gram Atomic Weight: A mass in grams numerically equal to the atomic weight of an element.

Gram Molecular Weight (Gram-Mole): Mass in grams numerically equal to the molecular weight of a substance.

Gram-Rad: Unit of integral dose equal to 100 ergs.

Graphite: A form of carbon in which the atoms are hexagonally arranged in planes. Commonly used for moderators because it can be made in compact, fairly strong blocks, easily machined to close tolerances, and because the prolonged baking at high temperature used in its manufacture helps eliminate impurities that might absorb neutrons.

Gravitation: Force of attraction existing between all material bodies in the universe. The magnitude of the force between any two bodies is proportional to the product of the masses of the two bodies and inversely proportional to the square of the distance between them.

Grenz Rays: X rays produced at voltages of 5 to 20 kVp, intended primarily for surface therapy.

Ground State: The state of a nucleus, atom, or molecule at its lowest energy. All other states are "excited."

–H–

Half-Life, Biological: The time required for the body to eliminate one-half of an administered dosage of any substance by regular processes of elimination. Approximately the same for both stable and radioactive isotopes of a particular element.

Half-Life, Effective: Time required for a radioactive element in an animal body to be diminished 50 percent as a result of the combined action of radioactive decay and biological elimination.

$$\text{Effective half-life} = \frac{\text{Biological half-life} \times \text{Radioactive half-life}}{\text{Biological half-life} + \text{Radioactive half-life}}$$

Half-life, Radioactive: Time required for a radioactive substance to lose 50 percent of its activity by decay. Each radionuclide has a unique half-life.

Half Value Layer (Half Thickness) (HVL): The thickness of a specified substance which, when introduced into the path of a given beam of radiation, reduces the exposure rate by one-half.

Hardness (x rays): A relative specification of the quality or penetrating power of x rays. In general, the shorter the wavelength the harder the radiation.

Health, Radiological: The art and science of protecting human beings from injury by radiation, and promoting better health through beneficial applications of radiation.

Heredity: Transmission of characters and traits from parent to offspring.

Hertz: Unit of frequency equal to one cycle per second.

Hot Cell: A heavily shielded enclosure for handling and processing (by remote means or automatically) or storing highly radioactive materials.

Hygiene, Radiation: Radiological health.

–I–

Immunity: The power which a living organism possesses to resist and overcome infection.

Implant (Radiology): Encapsulated radioactive material embedded in a tissue for therapy. It may be permanent (seed) or temporary (needle).

Insulating Core Transformer (ICT): A high voltage power supply consisting of a transformer, the core of which is separated into insulated segments, each having a secondary winding which drives its own rectifier. The rectifier outputs are connected in series to produce the high voltage. An accelerating column may be directly attached to the high voltage terminal, or it may be physically separated from the unit and connected to it by a high-voltage shielded cable.

Intensifying Screen: Sheet of cardboard or other substance coated with fluorescent material, placed in contact with the film in radiography. The x or gamma rays excite the fluorescent substance. The light thus emitted adds to the radiation effect on the film and produces an image of greater density for a given exposure. Sheets of thin lead may be used in industrial radiography with very high energy radiation. In this case, the increased effect is due largely to secondary electrons and x rays emitted by the lead.

Intensity: Amount of energy per unit time passing through a unit area perpendicular to the line of propagation at the point in question.

Interlock: A device, usually electrical and (or) mechanical, to prevent activation of a control until a preliminary condition has been met, or prevent hazardous operations. Its purpose usually is safety.

Internal Conversion: One of the possible mechanisms of decay from the metastable state (isomeric transition) in which the transition energy is transferred to an orbital electron, causing its ejection from the atom. The ratio of the number of internal conversion electrons to the number of gamma quanta emitted in the de-excitation of the nucleus is called the "conversion ratio."

Ion: Atomic particle, atom, or chemical radical bearing an electrical charge, either negative or positive.

Ion Exchange: A chemical process involving the reversible interchange of ions between a solution and a particular solid material such as an ion exchange resin consisting of a matrix of insoluble material interspersed with fixed ions of opposite charge.

Ionization: The process by which a neutral atom or molecule acquires a positive or negative charge.

> **Primary Ionization**: (1) In collision theory: the ionization produced by the primary particles as contrasted to the "total ionization" which includes the "secondary ionization" produced by delta rays. (2) In counter tubes: The total ionization produced by incident radiation without gas amplification.
>
> **Secondary Ionization**: Ionization produced by delta rays.
>
> **Specific Ionization**: Number of ion pairs per unit length of path of ionizing radiation in a medium; e.g., per cm. of air or per micron of tissue.
>
> **Total Ionization**: The total electric charge of one sign on the ions produced by radiation in the process of losing its kinetic energy. For a given gas, the total ionization is closely proportional to the initial ionization and is nearly independent of the nature of the ionizing radiation. It is frequently used as a measure of radiation energy.

Ionization Density: Number of ion pairs per unit volume.

Ionization Path (Track): The trail of ion pairs produced by an ionizing radiation in its passage through matter.

Ionizing Event: Any occurrence of a process in which an ion or group of ions is produced.

Ion Pair: Two particles of opposite charge, usually referring to the electron and positive atomic or molecular residue resulting after the interaction of ionizing radiation with the orbital electrons of atoms.

Irradiation: Exposure to radiation.

Isobars: Nuclides having the same mass number but different atomic numbers.

Isochronous Cyclotron (Azimuthally Varying Field [AVF] or Sector Focused Cyclotron): A cyclotron which uses a constant accelerating frequency and focuses the particles by means of wedge-shaped sectors on the magnet poles.

Isodose Chart: Chart showing the distribution of radiation in a medium by means of lines or surfaces drawn through points receiving equal doses. Isodose charts have been determined for beams of x rays traversing the body, for radium applicators used for intracavitary or interstitial therapy, and for working areas where x rays or radioactive nuclides are employed.

Isodose Curve: A curve depicting loci of identical radiation doses in a structure.

Isomers: Nuclides having the same number of neutrons and protons but capable of existing, for a measurable time, in different quantum states with different energies and radioactive properties. Commonly, the isomer of higher energy decays to one with lower energy by the process of isomeric transition.

Isotones: Nuclides having the same number of neutrons in their nuclei.

Isotopes: Nuclides having the same number of protons in their nuclei, and hence the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Almost identical chemical properties exist between isotopes of a particular element. The term should not be used as a synonym for nuclide.

Stable Isotope: A non-radioactive isotope of an element.

Isotope Effect (Chemistry): The effect of the difference in the mass between isotopes of an element on the rate and/or equilibria of chemical transformations.

Isotope Separation: Process in which a mixture of isotopes of an element is separated into its component isotopes, or in which the abundance of isotopes in such a mixture is changed.

–J–

Joule: The unit for work and energy, equal to one newton expended along a distance of one meter (1J = 1N × 1m).

–K–

Kerma: The sum of the initial kinetic energies of all charged particles liberated by indirectly ionizing particles in a volume, divided by the mass of matter in that volume.

Kilo Electron Volt (keV): One thousand electron volts, 10^3 eV.

Kilovolt (kV): A unit of electrical potential difference, equal to 1,000 volts.

Kilovolt Peak (kVp): The crest value in kilovolts of the potential difference of a pulsating potential generator. When only half the wave is used, the value refers to the useful half of the cycle.

Klein-Nishina Formula: A formula that expresses the cross section of an unbound electron for scattering of a photon in the Compton effect, as a function of the energy of the photon. The term usually refers to the integral Klein-Nishina formula, which gives the total cross section for the process. The differential Klein-Nishina formula gives the differential cross section for scattering at a given angle. Because of the confidence with which photon-electron interactions can be interpreted (by using the Klein-Nishina formula), the Compton effect is important in the analysis of energy and polarization of gamma rays from many sources.

–L–

Labeled Compound: A compound consisting, in part, of labeled molecules. By observations of radioactivity or isotopic composition, this compound or its fragments may be followed through physical, chemical, or biological processes.

Labeled Molecule: A molecule containing one or more atoms distinguished by non-natural isotopic composition (with radioactive or stable isotopes).

Lag Time: The time between the occurrence of the primary ionizing event and the occurrence of the count.

Laser: Light amplification by stimulated emission of radiation. The laser region is that portion of the spectrum which includes ultra-violet, visible light, and infrared. (See Laser Definitions and Abbreviations, page 442.)

Latent Period: The period or state of seeming inactivity between the time of exposure of tissue to an injurious agent and response.

LD_{50} (Radiation Dose): (*See* Dose, Median Lethal.)

Lead Equivalent: The thickness of lead affording the same attenuation, under specified conditions, as the material in question.

Lepton: One of a class of light elementary particles (having small mass). Specifically, an electron, a positron, a neutrino, an antineutrino, a muon, or an antimuon. (*See* Baryon, Meson.)

Lesion: A hurt, wound, or local degeneration.

Leukemia: A disease in which there is great overproduction of white blood cells, or a relative overproduction of immature white cells, and great enlargement of the spleen. The disease is variable, at times running a more chronic course in adults than in children. It is almost always fatal. It can be produced in some animals by long-continued exposure to low doses of ionizing radiation.

Linear Accelerator: A device for accelerating charged particles. It employs alternate electrodes and gaps arranged in a straight line, so proportioned that when potentials are varied in the proper amplitude and frequency, particles passing through the waveguide receive successive increments of energy.

Localization, Selective (Biology): Accumulation of a particular nuclide to a significantly greater degree in certain cells or tissues. (*See* Absorption Ratio, Differential.)

–M–

Mass: The material equivalent of energy–different from weight in that it neither increases nor decreases with gravitational force.

Critical Mass: The minimum mass of fissile material which can be made critical with a specified geometrical arrangement and material composition.

Relativistic Mass: The increased mass associated with a particle when its velocity is increased. The increase in mass becomes appreciable only at velocities approaching the velocity of light, 3×10^{10} cm/sec.

Mass Defect: Difference between the mass of the nucleus as a whole and the sum of the component nucleon masses.

Mass-Energy Relation: The name sometimes given to the equation $E = mc^2$.

Mass Numbers: The number of nucleons (protons and neutrons) in the nucleus of an atom. (Symbol: A)

Maximum Credible Accident: The worst accident in a reactor or nuclear energy installation that, by agreement, need be taken into account in devising protective measures.

Mean Free Path: The average distance that particles of a specified type travel before a specified type (or types) of interaction in a given medium. The mean free path may thus be specified for all interactions (i.e., total mean free path) or for particular types of interaction such as scattering, capture, or ionization.

Mean Life: The average lifetime for an atomic or nuclear system in a specified state. For an exponentially decaying system, the average time for the number of atoms or nuclei in a specified state to decrease by a factor of e (2.718. . .).

Mega Electron Volt (MeV): One million electron volts, 10^6 eV.

Meson: One of a class of medium-mass, short-lived elementary particles with a mass between that of the electron and that of the proton. Examples: Pi mesons (pions) and K-mesons (kaons). (*See* Baryon, Lepton.)

Metabolism: The sum of all physical and chemical processes by which living organized substance is produced and maintained and by which energy is made available for the uses of the organism.

Metastable State: An excited nuclear state having a half-life long enough to be observed.

Metastasis: The transfer in the body of malignant neoplastic cells from the original or parent site to one more distant.

Micron: Unit of length equal to 10^{-6} meters. (Symbol: μ).

Microwave: An electromagnetic wave having a wavelength of approximately 1 meter to 1 millimeter corresponding to frequencies of about 300 to 300,000 megacycles per second. (*See* Glossary of Microwave Terms.)

Mil: Unit of length equal to one-thousandth of an inch.

Milliroentgen (mR): A submultiple of the roentgen, equal to one one-thousandth of a roentgen. (*See* Roentgen.)

Moderator: Material used to moderate or slow down neutrons from the high energies at which they are released.

Molecular Weight: The sum of the atomic weights of all the atoms in a molecule.

Molecule: Smallest quantity of a compound which can exist by itself and retain all properties of the original substance.

Momentum: The product of the mass of a body and its velocity, MKSA units, kg-m/sec.

Monte Carlo Method: A method permitting the solution by means of a computer of problems of physics, such as those of neutron transport, by determining the history of a large number of elementary events by the application of the mathematical theory of random variables.

Monitoring: Periodic or continuous determination of the amount of ionizing radiation or radioactive contamination present in an occupied region.

Area Monitoring: Routine monitoring of the radiation level or contamination of a particular area, building, room, or equipment. Some laboratories or operations distinguish between routine monitoring and survey activities.

Personnel Monitoring: Monitoring any part of an individual, his breath, or excretions, or any part of his clothing.

Mutation: Alteration of the usual hereditary pattern, usually sudden.

–N–

N-Unit: That quantity of neutron radiation measured in a condenser R-meter that will produce the same amount of ionization as one roentgen of x radiation.

Neoplasm: A new growth of cells which is more or less unrestrained and not governed by the usual limitations of normal reproduction. ***Benign:*** some degree of growth restraint and no spread to distant parts. ***Malignant:*** growth invades tissues or spreads to distant parts, or both.

Neutrino: A neutral particle of very small rest mass originally postulated to account for the continuous distribution of energy among particles in the beta-decay process.

Neutron Cycle: The average energy, interaction and migration history of neutrons in a reactor, beginning with fission and continuing until they have leaked out or have been absorbed.

Neutrons, Prompt: Neutrons accompanying the fission process without measurable delay.

Newton: The unit of force, which when applied to a one kilogram mass will give it an acceleration of one meter per second per second. ($1N = 1kg \times 1m/1s^2$)

Nuclear Fusion: (*See* Reaction, Thermonuclear.)

Nucleon: Common name for a constituent particle of the nucleus. Applied to a proton or neutron.

Nucleus: (Biological) A definitely delineated body within the cell, containing the chromosomes. (Nuclear) That part of an atom in which the total positive electric charge and most of the mass is concentrated.

Nuclide: A species of atom characterized by the constitution of its nucleus. The nuclear constitution is specified by the number of protons (Z), number of neutrons (N), and energy content; or, alternatively, by the atomic number (Z), mass number A = (N + Z), and atomic mass. To be regarded as a distinct nuclide, the atom must be capable of existing for a measurable time. Thus, nuclear isomers are separate nuclides, whereas promptly decaying excited nuclear states and unstable intermediates in nuclear reactions are not so considered.

–O–

Organ: Group of tissues which together perform one or more definite functions in a living body.

Osmosis: The passage of pure solvent from the lesser to the greater concentration when two solutions are separated by a membrane which selectively prevents the passage of solute molecules, but is permeable to the solvent.

Osmotic: Pertaining to osmosis.

–P–

Packing Fraction: The ratio (Δ/A) of the mass defect (Δ), and mass number (A), of a nuclide.

Pair Production: An absorption process for x and gamma radiation in which the incident photon is annihilated in the vicinity of the nucleus of the absorbing atom, with subsequent production of an electron and positron pair. This reaction only occurs for incident photon energies exceeding 1.02 MeV.

Parent: A radionuclide which, upon disintegration, yields a specified nuclide–either directly or as a later member of a radioactive series.

Path, Mean Free: Average distance a particle travels between collisions.

Periodic Table: An arrangement of chemical elements in order of increasing atomic number. Elements of similar properties are placed one under the other, yielding groups and families of elements. Within each group there is a gradation of chemical and physical properties but, in general, a similarity of chemical behavior. From group to group, however, there is a progressive shift of chemical behavior from one end of the table to the other.

Permeable: Affording passage or penetration.

Phantom: A volume of material approximating as closely as possible the density and effective atomic number of tissue. Ideally a phantom should behave in respect to absorption of radiation in the same manner as tissue. Radiation dose measurements made within or on a phantom provide a means of determining the radiation dose within or on a body under similar exposure conditions. Some materials commonly used in phantoms are water, Masonite, pressed wood, and beeswax.

Phosphorescence: Emission of radiation by a substance as a result of previous absorption of radiation of shorter wavelength. In contrast to fluorescence, the emission may continue for a considerable time after cessation of the exciting irradiation.

Photoelectric Effect: Process by which a photon ejects an electron from an atom. All the energy of the photon is absorbed in ejecting the electron and in imparting kinetic energy to it.

Photofluorography: (*See* Fluorography.)

Photon: A quantity of electromagnetic energy (E) whose value in joules is the product of its frequency (ν) in hertz and Planck constant (h). The equation is: $E = h\nu$.

Photosynthesis: The production of carbohydrates by green plants in the presence of sunlight through the agency of chlorophyll.

Physics, Health: A science and profession devoted to the protection of man and his environment from unnecessary radiation exposure.

Pile: (*See* Reactor, Nuclear.)

Planck Constant: A natural constant of proportionality (h) relating the frequency of a quantum of energy to the total energy of the quantum:

$$h = \frac{E}{\nu} = 6.6256 \times 10^{-34} \text{ J sec.}$$

Plateau: As applied to radiation detector chambers, the level portion of the counting rate-voltage curve where changes in operating voltage introduce minimum changes in the counting rate.

Plateau Slope, Relative: The relative increase in the number of counts as function of voltage expressed in percentage per 100 volts increase above the Geiger threshold.

Poison: Material of high absorption cross section which absorbs neutrons unproductively and reduces the reactivity of a reactor.

Polycythemia: A disease characterized by overproduction of red blood cells.

Polymerization: Union of two or more molecules of a compound to form a more complex molecule.

Positron: Particle equal in mass to the electron and having an equal but positive charge.

Potential Ionization: The potential necessary to separate one electron from an atom, resulting in the formation of an ion pair.

Potential Difference: Work required to carry a unit positive charge from one point to another.

Power, Nuclear: Useful power released in exothermic nuclear reactions.

Power, Stopping: A measure of the effect of a substance upon the kinetic energy of a charged particle passing through it.

Pressure Vessel, Reactor: A reactor vessel designed to withstand a substantial operating pressure.

Process, Regenerative: The process by which damaged or destroyed cells are replaced by new ones of the same type.

Prompt Gamma Radiation: Gamma radiation accompanying the fission process without measurable delay.

Proportional Region: Voltage range in which the gas amplification is greater than one, and in which the charge collected is proportional to the charge produced by the initial ionizing event.

Protium: A name sometimes applied to the hydrogen isotope of mass 1 to distinguish it from deuterium and tritium.

Proton: Elementary nuclear particle with a positive electric charge equal numerically to the charge of the electron and a mass of 1.007277 mass units.

Purpura: Large hemorrhagic spots in or under the skin or mucous tissues.

–Q–

Quality (Radiology): The characteristic spectral-energy distribution of x radiation. It is usually expressed in terms of effective wave lengths or half-value layers of a suitable material; e.g., up to 20 kV, cellophane; 20 to 120 kVp, aluminum; 120 to 400 kVp, copper; over 400 kVp, tin.

Quality Factor (QF): The linear-energy-transfer-dependent factor by which absorbed doses are multiplied to obtain (for radiation protection purposes) a quantity that expresses–on a common scale for all ionizing radiations–the effectiveness of the absorbed dose.

Quantum: An observable quantity is said to be "quantized" when its magnitude is, in some or all of its range, restricted to a discrete set of values. If the magnitude of the quantity is always a multiple of a definite unit, then that unit is called the quantum (of the quantity). For example, the quantum or unit of orbital angular momentum is h, and the quantum of energy of electromagnetic radiation of frequency ν is $h\nu$. In field theories, a field (or the field equations) is quantized by application of a proper quantum-mechanical procedure. This results in the existence of a fundamental field particle, which may be called the field quantum. Thus, the photon is a quantum of the electromagnetic field and in nuclear field theories the meson is considered the quantum of the nuclear field.

Quantum Theory: The concept that energy is radiated intermittently in units of definite magnitude called quanta, and absorbed in a like manner.

Quenching: The process of inhibiting continuous or multiple discharge in a counter tube which uses gas amplification.

Quenching Vapor: Polyatomic gas used in Geiger-Mueller counters to quench or extinguish avalanche ionization.

–R–

Rabbit: A small container propelled, usually pneumatically or hydraulically, through a tube in a nuclear reactor to expose substances experimentally to the radiation and neutron flux of the active section. Used for rapid removal of samples with very short half-lives.

Rad: The unit of absorbed dose equal to 0.01 J/kg in any medium. (*See* Absorbed Dose.) (Written: rad.)

Radiation: (1) The emission and propagation of energy through space or through a material medium in the form of waves; for instance, the emission and propagation of electromagnetic waves, or of sound and elastic waves. (2) The energy propagated through space or through a material medium as waves; for example, energy in the form of electromagnetic waves or of elastic waves. The term radiation or radiant energy, when unqualified, usually refers to electromagnetic radiation. Such radiation commonly is classified, according to frequency, as Hertzian, infrared, visible (light), ultra-violet, x ray, and gamma ray. (*See* Photon.) (3) By extension, corpuscular emissions, such as alpha and beta radiation, or rays of mixed or unknown type, as cosmic radiation.

Annihilation Radiation: Photons produced when an electron and a positron unite and cease to exist. The annihilation of a positron-electron pair results in the production of two photons, each of 0.51 MeV energy.

Background Radiation: Radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present. There may also be background radiation due to the presence of radioactive substances in other parts of the building, in the building material itself, etc.

Characteristic (Discrete) Radiation: Radiation originating from an atom after removal of an electron or excitation of the nucleus. The wavelength of the emitted radiation is specific, depending only on the nuclide and particular energy levels involved.

Direct Radiation: Obsolete term for "leakage radiation."

External Radiation: Radiation from a source outside the body–the radiation must penetrate the skin.

Infrared Radiation: Invisible thermal radiation whose wavelength is longer than the red segment of the visible spectrum.

Internal Radiation: Radiation from a source within the body (as a result of deposition of radionuclides in body tissues.)

Ionizing Radiation: Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter.

Leakage (Direct) Radiation: All radiation coming from the source housing except the useful beam.

Monochromatic Radiation: Electromagnetic radiation of a single wavelength, or radiation in which all the photons have the same energy.

Monoenergetic Radiation: Radiation of a given type (alpha, beta, neutron, gamma, etc.) in which all particles or photons originate with and have the same energy.

Primary Radiation: The useful beam of an x-ray tube.

Scattered Radiation: Radiation which during its passage through a substance, has been deviated in direction. It may also have been modified by a decrease in energy.

Secondary Radiation: Radiation resulting from absorption of other radiation in matter. It may be either electromagnetic or particulate.

Stem Radiation: X rays given off from parts of the anode other than the target, particularly from the target support.

Stray Radiation: The sum of leakage and scattered radiation.

Radioactivity: The property of certain nuclides of spontaneously emitting particles or gamma radiation or of emitting x radiation following orbital electron capture or of undergoing spontaneous fission.

Artificial Radioactivity: Manmade radioactivity produced by particle bombardment or electromagnetic irradiation, as opposed to natural radioactivity.

Induced Radioactivity: Radioactivity produced in a substance after bombardment with neutrons or other particles. The resulting activity is "natural radioactivity" if formed by nuclear reactions occurring in nature, and "artificial radioactivity" if the reactions are caused by man.

Natural Radioactivity: The property of radioactivity exhibited by more than fifty naturally occurring radionuclides.

Radioautograph: (*See* Autoradiograph.)

Radiobiology: That branch of biology which deals with the effects of radiation on biological systems.

Radiochemistry: The aspects of chemistry connected with radionuclides and their properties, with the behavior of minute quantities of radioactive materials by means of their radioactivity, and the use of radionuclides in the study of chemical problems.

Radiography: The making of shadow images on photographic emulsion by the action of ionizing radiation. The image is the result of the differential attenuation of the radiation in its passage through the object being radiographed.

Radiology: That branch of medicine which deals with the diagnostic and therapeutic applications of radiant energy including x rays and radionuclides.

Radiopharmaceutical: A pharmaceutical compound which has been tagged with a radionuclide

Radioresistance: Relative resistance of cells, tissues, organs, or organisms to the injurious action of radiation. The term may also be applied to chemical compounds or to any substances. (*See* Radiosensitivity.)

Radiosensitivity: Relative susceptibility of cells, tissues, organs, organisms, or any living substance to the injurious action of radiation. Radioresistance and radiosensitivity are currently used in a comparative sense, rather than in an absolute one.

Rare Earth: Any of the series of very similar metals ranging in atomic number from 57 through 71.

Rate, Recovery: The rate at which recovery takes place after radiation injury. It may proceed at different rates for different tissues. "Differential recovery rate:" Among tissues recovering at different rates, those having slower rates will ultimately suffer greater damage from a series of successive irradiations. This differential effect is considered in fractionated radiation therapy if the neoplastic tissues have a slower recovery rate than surrounding normal structures.

Reaction (Nuclear): An induced nuclear disintegration; i.e., a process occurring when a nucleus comes in contact with a photon, an elementary particle, or another nucleus. In many cases the reaction can be represented by the symbolic equation: $X + a \rightarrow Y + b$ or, in abbreviated form, $X(a,b)\ Y$. X is the target nucleus, a is the incident particle or photon, b is an emitted particle or photon, and Y is the product nucleus.

Chain Reaction: Any chemical or nuclear process in which some products or energy released by the process are instrumental in the continuation or magnification of the process.

Endoergic Reaction: Reaction which absorbs energy.

Endothermic Reaction: Reaction which absorbs energy, specifically in the form of heat.

Exothermic Reaction: Reaction which liberates energy, specifically as heat.

Thermonuclear Reaction: A nuclear reaction in which the energy necessary for the reaction is provided by colliding particles possessing kinetic energy by virtue of their thermal agitation. Such reactions occur at appreciable rates only for temperatures of millions of degrees and higher. Their rate increases with temperature. The energy of most stars is believed to be derived from exothermic thermonuclear reactions.

Reactivity: A parameter, ρ, giving the deviation from criticality of a nuclear chain-reacting medium such that positive values correspond to a supercritical state and negative values to a subcritical state.

Reactor, Breeder: A reactor which produces more fissile material than it consumes; i.e., has a conversion ratio greater than unity.

Reactor, Converter: A reactor which produces fissile atoms from fertile atoms, but has a conversion ratio less than one.

Reactor, Nuclear: An apparatus in which nuclear fission may be sustained in a self-supporting chain reaction. A reactor includes fissionable material (fuel) such as uranium or plutonium, and moderating material (except fast reactors), and usually includes a reflector to conserve escaping neutrons, provision for heat removal, and measuring and control elements. The terms "pile" and "reactor" have been used interchangeably, with reactor now becoming more common. These terms usually are applied only to systems in which the reaction proceeds at a controlled rate, but they also have been applied to bombs. Reactors may be classified on various bases:

1. By Fuel Arrangement

Heterogeneous: Fissionable material, (fuel) and moderator are arranged as discrete bodies (usually in a regular pattern) of such dimensions that a non-homogeneous medium is presented to the neutrons.

Homogeneous: Fissionable material and moderator (if used) are so combined that an effectively homogeneous medium is presented to the neutrons. Such a mixture is represented either by a solution of fuel in moderator or by discrete particles whose dimensions are small in comparison with the neutron mean free path.

2. By Neutron Energy

Epithermal: A substantial fraction of fissions (e.g., 30 or 40 percent) are induced by neutrons of more than thermal energy.

Fast: A nuclear reactor in which there is little moderation of neutrons. Thus, fission is induced primarily by fast neutrons that have lost relatively little of the energy with which they were released. The slowing down of neutrons that does occur is due largely to inelastic scattering instead of elastic scattering. About 100,000 electron volts is regarded as the minimum value of mean energy of neutrons inducing fission for a reactor to be considered fast, with one-half to one-third MeV more common. Sometimes the fission threshold of ^{238}U is taken as the lower limit of the fast range. Reactors of this type have potentially high neutron economy.

Intermediate: Fission is induced predominantly by neutrons whose energies are greater than thermal, but much less than the energy with which neutrons are released in fission. From 0.5 to 100,000 electron volts may be taken roughly as the energy range of neutrons inducing fission in intermediate reactors. The neutron absorption resonances of the fuel may be important in this range.

Thermal: A nuclear reactor in which fission is induced primarily by neutrons of such energy that they are in substantial thermal equilibrium with the core material. A representative energy for thermal neutrons often is taken as 0.025 eV (2200 meters per second) which corresponds to the mean energy of neutrons in a Maxwellian distribution at 293°K, although most thermal reactors actually operate at a higher temperature. A moderator is an essential element of a thermal reactor.

3. By Use

Power: A reactor capable of providing useful mechanical power. In reactors now planned, this is done by generating energy (in the form of heat) conveyed at a temperature high enough for efficient conversion to mechanical work.

Power Breeder: A nuclear reactor designed to produce both useful power and fuel.

Production: A nuclear reactor designed primarily for large-scale production of transmutation products (e.g., plutonium).

Research: A reactor whose primary purpose is as a research tool. It may supply neutrons, other particles, and gamma radiation, and will include special provision for exposing samples (which may include living organisms) to these fluxes. It may provide transmutation products as well as have special experimental facilities.

4. Special

High Flux: Since a high flux results from a high rate of fission per unit volume, a high-flux reactor operates at high power density.

High Temperature: Roughly, the temperature may be considered high in this connection if it is great enough to permit generation of mechanical power at good efficiency.

Recoil, Aggregate: The ejection, from the surface of a sample, of a cluster of atoms attached to one atom that is recoiled as the result of alpha particle emission. Although the phenomenon may be quite common, the amount of matter thus carried away is so small as to be undetectable unless it is strongly radioactive. It is observed with strong preparations of alpha-active materials of high specific activity—such as nearly pure polonium compounds—as a migration of a small fraction of the radioactivity onto clean surfaces in the vicinity.

Recombination: The return of an ionized atom or molecule to the neutral state.

Recovery (Radiobiology): The return toward normal of a particular cell, tissue, or organism after radiation injury.

Reflector: A layer or structure of material between the shield and core of a reactor, designed to reduce the escape of neutrons and return them to the core. Neutrons entering the reflector are scattered randomly, some of them many times. A large fraction may ultimately return to the core. It is possible to design a reflector which will return more than 90% of the neutrons that would otherwise be lost. Requirements for a good reflector are similar to those for a good moderator: Its atoms should have low neutron-absorption cross section and high scattering cross section. Low atomic mass is not important. A reflector's effectiveness increases with its thickness, approaching a limiting factor when the thickness is several times the transport mean free path. Reflector savings is a measure of the decrease in critical core size obtained by the use of the reflector.

Relative Biological Effectiveness (RBE): The RBE is a factor used to compare the biological effectiveness of absorbed radiation doses (i.e., rads) due to different types of ionizing radiation, more specifically, it is the experimentally determined ratio of an absorbed dose of a radiation in question to the absorbed dose of a reference radiation required to produce an identical biological effect in a particular experimental organism or tissue. *NOTE: This term should not be used in radiation protection.* (*See* Quality Factor.)

Rem: A special unit of dose equivalent. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor, the distribution factor, and any other necessary modifying factors.

Rep: An obsolete special unit of absorbed dose.

Resolving Time, Counter: The minimum time interval between two distinct events which will permit both to be counted. It may refer to an electronic circuit, to a mechanical indicating device, or to a counter tube.

Resonance Energy: The kinetic energy of an incident particle (expressed in the laboratory system) that makes the total energy of the system composed of the incident particle and the target nucleus close to the energy of a nuclear level of the compound nucleus.

Resonant Transformer: A transformer so designed that the inductance and distributed capacitance of its windings comprise a circuit which is in resonance at the frequency [illegible] the supplied power. As it does not require an iron core, insulation problems and weight are minimized. This principle is the basis of certain 1 and 2 million volt generators used to produce x rays and electron beams.

Respiratory System: The group of organs concerned with the exchange of oxygen and carbon dioxide in organisms. In higher animals this consists successively of the air passages through the mouth, nose, and throat, the trachea, the bronchi, the bronchioles, and the alveoli of the lungs.

R-Meter: (*See* Condenser R-Meter.)

Rod: A relatively long and slender body of material used in or with a nuclear reactor. It may contain fuel, absorber, fertile materials, or other material in which activation or transmutation is desired.

Control Rod: Any rod used to control the reaction rate in a nuclear reactor by changing the effective multiplication constant and hence the reaction rate's time derivative. It may be a fuel rod or a part of the moderator; in thermal reactors it commonly is a neutron absorber. Cadmium and boron (as boron steel) are suitable absorbing materials. Sometimes absorbing control rods are made of fertile material to utilize the neutrons absorbed in control. The term includes power control rod, regulating rod, safety rod, shim rod.

Fuel Rod: A rod-shaped body of nuclear fuel or a long, slender fuel assembly prepared for use in a reactor. A short fuel rod is called a "slug."

Regulating Rod: A control rod intended to accomplish rapid, fine adjustment of the reactivity of a nuclear reactor. It can usually move much more rapidly than a shim rod, but makes a smaller change in the reactor's reactivity. Its rapid and sometimes continuous readjustment may be accomplished by a servo system.

Safety Rod: An emergency control rod capable of shutting down a reactor very quickly, should the ordinary control system (e.g., regulating and shim rods) fail. Since it must be able to reduce the reactor's effective multiplication constant to much less than unity when inserted, it is withdrawn almost completely during normal operation. A safety rod may be suspended above the core by a magnetic coupling and allowed to fall in if power reaches a predetermined level.

Scram Rod: Safety rod.

Shim Rod: A control rod used for making occasional coarse adjustments in the reactivity of a nuclear reactor. It usually moves more slowly than a regulating rod and, singly or as one of a group, can make a greater total change in the reactivity. Its name is derived from analogy to a mechanical shim. A shim rod commonly is positioned so that the reactor will be just critical (reactivity = 0, effective multiplication constant = 1) when the regulating rod is near the middle of its range of travel.

Roentgen (R): The special unit of exposure. One roentgen equals 2.58×10^{-4} coulomb per kilogram of air. (*See* Exposure.)

Roentgenography: Radiography by means of x rays.

Roentgenology: That part of radiology which pertains to x rays.

Roentgen Rays: X rays.

Rutherford: An obsolete unit of radioactivity equivalent to 10^6 disintegrations per second.

–S–

Sarcoma: Malignant neoplasm composed of cells imitating the appearance of the supportive and lympathic tissues.

Scaler: An electronic device which registers current pulses received over a given time interval.

Binary Scaler: A scaler whose scaling factor is two per stage.

Decade Scaler: A scaler whose scaling factor is a power of ten.

Scanner, Rectilinear: A device which employs a moving collimated detector and a moving recorder to produce an image of the radionuclide distribution within an organ or gland.

Scanning (Medical): The process by which the spatial distribution of a radionuclide within an organ or gland in the body is visualized.

Scattering: Change of direction of subatomic particles or photons as a result of a collision or interaction.

Coherent Scattering: Scattering of photons or particles in which there are definite phase relationships between the incoming and the scattered waves. Coherence manifests itself in the interference between the waves scattered by two or more scattering centers. An example is the Bragg scattering of x rays and of neutrons by the regularly spaced atoms in a crystal, for which constructive interference occurs only at definite angles, called "Bragg angles."

Compton Scattering: The scattering of a photon by an electron. Part of the energy and momentum of the incident photon is transferred to the electron and the remaining part is carried away by the scattered photon.

Elastic Scattering: Scattering caused by elastic collisions, and therefore conserving kinetic energy of the system. Rayleigh scattering is a form of elastic scattering.

Incoherent Scattering: Scattering of photons or particles in which the scattering elements act independently of one another; there are no definite phase relationships among the different parts of the scattered beam. The intensity of the scattered radiation at any point is obtained by adding the intensities of the scattered radiation reaching this point from the independent scattering elements.

Inelastic Scattering: The type of scattering which results in the nucleus being left in an excited state and the total kinetic energy being decreased.

Multiple Scattering: Scattering of a particle or a photon in which the final displacement is the vector sum of many–usually small–displacements.

Plural Scattering: Scattering of a particle or a photon in which the final deflection is the vector sum of a small number of displacements.

Rayleigh Scattering: The elastic scattering of a photon without loss of photonic energy. Sometimes referred to as coherent scattering.

Single Scattering: The deflection of a particle from its original path owing to one encounter with a single scattering center in the material traversed.

Scattering Coefficient, Compton: That fractional decrease in the energy of a beam of x or gamma radiation in an absorber due to the energy carried off by scattered photons in the Compton effect.

Scintillation Camera: A device for visualizing the spatial distribution of a radionuclide within an organ or gland in the body. The gamma camera uses a stationary NaI(Tl) crystal as the detection element. Positioning signals are generated from a bank of photomultiplier tubes and applied to a cathode ray tube. Counts are integrated on film to obtain an image of the radionuclide distribution.

Scram: Emergency stopping of a nuclear reactor, usually by dropping safety rods. This may be arranged to occur automatically at a predetermined neutron flux or under other danger conditions, the reaching of which causes the monitors and associated equipment to generate a scram signal. To shut down a reactor by causing a scram.

Sealed Source: A radioactive source sealed in an impervious container which has sufficient mechanical strength to prevent contact with and dispersion of the radioactive material under the conditions of use and wear for which it was designed.

Selector, Pulse Height: A circuit designed to select and pass voltage pulses in a certain range of amplitudes.

Series, Radioactive: A succession of nuclides, each of which transforms by radioactive disintegration into the next until a stable nuclide results. The first member is called the "parent," the intermediate members are called "daughters," and the final stable member is called the "end product."

Shield: A body of material used to prevent or reduce the passage of particles or radiation. A shield may be designated according to what it is intended to absorb (as a gamma-ray shield or neutron shield), or according to the kind of protection it is intended to give (as a background, biological, or thermal shield). The shield of a nuclear reactor is a body of material surrounding the reactor to prevent the escape of neutrons and radiation into a protected area, which frequently is the entire space external to the reactor. It may be required for the safety of personnel or to reduce radiation enough to allow use of counting instruments for research or for locating contamination or airborne radioactivity.

Shutdown: Procedure of stopping a chain reaction by bringing the reactor to a subcritical condition (effective multiplication constant less than 1). State of a reactor after being shut down.

Sickness, Radiation: (Radiation Therapy): A self-limited syndrome characterized by nausea, vomiting, diarrhea, and psychic depression, following exposure to appreciable doses of ionizing radiation, particularly to the abdominal region. Its mechanism is unknown and there is no satisfactory remedy. It usually appears a few hours after irradiation and may subside within a day. It may be sufficiently severe to necessitate interrupting the treatment series or to incapacitate the patient. (General): The syndrome associated with intense acute exposure to ionizing radiations.

Sigmoid Curve: S-shaped curve, often characteristic of a dose-effect curve in radiobiological studies.

Softness: A relative specification of the quality or penetrating power of x rays. In general, the longer the wave length the softer the radiation.

Spallation: A term used to denote a nuclear reaction induced by high-energy bombardment and involving the ejection of more than two or three particles (neutrons, protons, deuterons, alpha particles, etc.).

Specific Activity: Total activity of a given nuclide per gram of a compound, element, or radioactive nuclide.

Specific Gamma-Ray Constant: For a nuclide emitting gamma radiation, the product of exposure rate at a given distance from a point source of that nuclide and the square of that distance divided by the activity of the source, neglecting attenuation.

Spectrograph, Mass: A device for analyzing a substance in terms of the ratios of mass to charge of its components, usually restricted to devices which produce a focused mass spectrum of lines on a photographic plate.

Spectrometer, Mass: A device similar to the mass spectrograph but designed so that the beam constituents of a given mass-to-charge ratio are focused on an electrode and detected or measured electrically.

Spectrum: A visual display, a photographic record, or a plot of the distribution of the intensity of radiation of a given kind as a function of its wavelength, energy, frequency, momentum, mass, or any related quantity.

Standard, Radioactive: A sample of radioactive material, usually with a long half-life, in which the number and type of radioactive atoms at a definite reference time is known. It may be used as a radiation source for calibrating radiation measurement equipment.

Statcoulomb (Electrostatic Unit of Charge): That quantity of electric charge which, when placed in a vacuum one cm distant from an equal and like charge, will repel it with a force of one dyne (abbreviated: esu). Preferred name for this unit is franklin (abbreviated: Fr).

Sterility (Biological): Temporary or permanent incapability to reproduce.

Streaming: The increased transmission of electromagnetic or particulate radiation through a medium resulting from the presence of extended voids or other regions of low attenuation. (Also called channeling effect.)

Stringer: A long structure occupying a hole through the shield, and sometimes into the active section, of a nuclear reactor. Its removal permits access to the core for inserting experimental materials. If it is part of a large graphite reactor, for instance, part of its length may consist of graphite blocks keyed together to permit withdrawal as a unit.

S.U.: Strontium unit. 1 pCi ^{90}Sr/gCa

Subcritical (Fissile System): Having an effective multiplication constant less than one, so that a self-supporting chain reaction cannot be maintained.

Supercritical (Fissile System): Having an effective multiplication constant greater than one, so that the rate of reaction rises.

Survey, Radiological: Evaluation of the radiation hazards incident to the production, use, or existence of radioactive materials or other sources of radiation under specific conditions. Such evaluation customarily includes a physical survey of the disposition of materials and equipment, measurements or estimates of the levels of radiation that may be involved, and sufficient knowledge of processes using or affecting these materials to predict hazards resulting from expected or possible changes in materials or equipment.

Synchrocyclotron: A cyclotron which compensates for the relativistic mass increase of the particles as they reach high energy by reducing the accelerating frequency so as to match exactly the slower revolutions of the accelerated particles.

Synchrotron: An accelerator in which particles are accelerated around a circular path by radiofrequency electric fields. The magnetic guiding and focusing fields are increased synchronously to match the energy gained by the particles so that the orbit radius remains constant. (*See* Cyclotron, Synchrocyclotron.)

Syndrome: The complex of symptoms associated with any disease.

–T–

Target Theory (Hit Theory): A theory explaining some biological effects of radiation on the basis that ionization, occurring in a discrete volume (the target) within the cell, directly causes a lesion which subsequently results in a physiological response to the damage at that location. One, two, or more "hits" (ionizing events within the target) may be necessary to elicit the response.

Therapy: Medical treatment of a disease.

Brachytherapy (Therapy at short distances): The treatment of disease with sealed radioactive sources placed near, or inserted directly into, the diseased area.

Contact Radiation Therapy: X ray therapy with specially constructed tubes in which the target-skin distance is very short (less than 2 cm). The voltage is usually 40 to 60 kV.

Radiation Therapy: Treatment of disease with any type of radiation.

Rotation Therapy: Radiation therapy during which either the patient is rotated before the source of radiation or the source is revolved around the patient. In this way, a larger dose is built up at the center of rotation within the patient's body than on any area of the skin.

Teletherapy (Therapy at long distance): The treatment of disease with gamma radiation from a source located at a distance from the patient.

Thermalization: Establishment of thermal equilibrium between neutrons and their surroundings.

Threshold, Photoelectric: The quantum of energy $h\nu_0$ that is just enough to release an electron from a given system in the photoelectric effect. The corresponding frequency, ν_0, and wavelength, λ_0, are the threshold frequency and wavelength respectively. For example, in the surface photoelectric effect, the threshold $h\nu_0$ for a particular surface is the energy of a photon which, when incident on the surface, causes the electron to emerge with zero kinetic energy.

Tissue Equivalent Material: Material made up of the same elements in the same proportions as they occur in a particular biological tissue. In some cases, the equivalence may be approximated with sufficient accuracy on the basis of effective atomic number.

Tracer, Isotopic: The isotope or non-natural mixture of isotopes of an element which may be incorporated into a sample to permit observation of the course of that element, alone or in combination, through a chemical, biological, or physical process. The observations may be made by measurement of radioactivity or of isotopic abundance.

Track: Visual manifestation of the path of an ionizing particle in a chamber or photographic emulsion.

Transition, Isomeric: The process by which a nuclide decays to an isomeric nuclide (i.e., one of the same mass number and atomic number) of lower quantum energy. Isomeric transitions, often abbreviated I.T., proceed by gamma ray and/or internal conversion electron emission.

Transmutation: Any process in which a nuclide is transformed into a different nuclide, or more specifically, when transformed into a different element by a nuclear reaction.

Tritium: The hydrogen isotope with one proton and two neutrons in the nucleus. (Symbol: $^3_1$H or T)

Triton: The nucleus of tritium, the hydrogen isotope of mass number 3, used as a nuclear projectile or as a product of a nuclear reaction.

Tube, Boron Counter: A counter tube filled with boron trifluoride (BF_3) and/or having electrodes coated with boron or boron compounds used for detecting slow neutrons by the (n,α) reaction of ^{10}B.

Tube, Electron Multiplier: A tube in which small electron currents are amplified by a cascade process employing secondary emission.

Tube, Photomultiplier: An electron multiplier tube in which the electrons initiating the cascade originate by photoelectric emission.

Tumor: In its general sense, a swelling. The term is often synonymous with neoplasm. A malignant tumor is capable of metastasizing.

–V–

Valence: Number representing the combining or displacing power of an atom; number of electrons lost, gained, or shared by an atom in a compound; number of hydrogen atoms with which an atom will combine, or which it will displace.

Van De Graaff Accelerator: An electrostatic machine in which electrical charge is carried into the high voltage terminal by a belt made of an insulating material moving at a high speed. The particles are then accelerated along a discharge path through a vacuum tube by the potential difference between the insulated terminal and the grounded end of the accelerator.

Volt: The unit of electromotive force (1V = 1W/ 1A).

Voltage, Operating: As applied to radiation detection instruments, the voltage across the electrodes in the detecting chamber required for proper detection of an ionizing event.

Voltage, Starting: For a counter tube, the minimum voltage that must be applied to obtain counts with the particular circuit with which it is associated.

Volume, Sensitive: That portion of a counter tube or ionization chamber which responds to a specific radiation.

–W–

Water, Activated: A transient, chemically reactive state created in water by absorbed ionizing radiation.

Water, Heavy: Popular name for water of which the hydrogen component is deuterium.

Watt: The unit of power equal to one joule per second (1W = 1J/1s).

Wavelength: Distance between any two similar points of two consecutive waves (λ) for electromagnetic radiation. The wavelength is equal to the velocity of light (c) divided by the frequency of the wave (ν), $\lambda = c/\nu$. The "effective wavelength" is the wavelength of monochromatic x rays which would undergo the same percentage attenuation in a specified filter as the heterogeneous beam under consideration.

Wave Motion: The transmission of a periodic motion or vibration through a medium or empty space. (Transverse): Wave motion in which the vibration is perpendicular to the direction of propagation. (Longitudinal): Wave motion in which the vibration is parallel to the direction of propagation.

–X–

X Rays: Penetrating electromagnetic radiations whose wave lengths are shorter than those of visible light. They are usually produced by bombarding a metallic target with fast electrons in a high vacuum. In nuclear reactions, it is customary to refer to photons originating in the nucleus as gamma rays, and those originating in the extranuclear part of the atom as x rays. These rays are sometimes called roentgen rays after their discoverer, W. C. Roentgen.

Laser Definitions and Abbreviations*

Angstrom (Å): A unit measure of wavelength equal to 10^{-10} meter or 10^{-4} micron.

Beam Divergence: The angle of beam spread measured in milliradians (1 milliradian = 3.4 minutes of arc).

Closed Installation: Any location where lasers are used which will be closed to personnel when a laser is operating. Useful adjuncts are remote-control firing and television monitoring of the target area.

C. W. Laser: A continuous wave laser, as distinguished from pulsed lasers.

Decibel (dB): A unit used to express a beam intensity ratio. The decibel is equal to ten times the logarithm of the beam intensity ratio expressed by the equation, $n(dB) = 10 \log_{10} (P_1 \div P_2)$, where P_1 and P_2 designate two amounts of power density or energy density and n the number of decibels corresponding to their ratio.

Energy Density: The intensity of electromagnetic radiation energy per unit area per pulse expressed as joules per square centimeter (J/cm^2).

Gas Laser: A type of laser in which the laser action takes place in a gas medium, usually a c.w. laser.

Joule (J): A unit of energy used in describing a single pulsed output of a laser. It is equal to one watt-second or 0.239 calories.

Joule per Square Centimeter (J/cm^2): A unit of energy density of pulsed lasers used in measuring the amount of energy per unit area of absorbing surface, or per unit area of a laser beam.

Laser: Light amplification by stimulated emission of radiation, sometimes referred to as an "optical maser."

Laser Control Area: Any area which contains one or more lasers and in which the activity of employees is subject to control and supervision.

Maser: Microwave amplification by stimulated emission of radiation. When used in the term optical maser, it is often interpreted as molecular amplification by stimulated emission of radiation.

Maximum Permissible Power Density or Energy Density: The intensity (power density or energy density) of laser radiation that, in the light of present medical knowledge, is not expected to cause detectable bodily injury to a person at any time during his lifetime.

Millimeters of Mercury (mm. Hg.): A unit of gas or air pressure (e.g., one atmosphere = 760 mm. Hg., or 29.92 in. Hg.).

Open Installation: Any location where lasers are used which will be open to operating personnel during laser operation and may or may not specifically restrict entry to casuals.

Optical Density (O.D.): A logarithmic expression of the attenuation afforded by a filter.

Optically Pumped Lasers: A type of laser that, as a general rule, derives energy from a noncoherent light source, such as a xenon flash lamp. Coherent light sources have also been used. These lasers are usually pulsed and are commonly called solid-state lasers, since a solid-state crystal such as ruby or glass is used.

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Output Power and Output Energy: The laser output power is used primarily to rate c.w. lasers since the energy delivered per unit time remains relatively constant (output measured in watts). In contrast, pulsed lasers deliver their energy output in pulses and their effects may best be categorized by energy output per pulse. The power output level of c.w. lasers is usually expressed in milliwatts (mW = 1/1000 watt) or watt range, pulsed lasers in the kilowatt range (kW = 1000 watts), and q-switched pulsed lasers in the megawatt (MW = million watts) or gigawatt range (GW = billion watts). Pulsed energy output is usually expressed in joules per pulse.

Partial Pressure of Oxygen: At sea level, oxygen exerts a partial pressure of 159 mm. Hg. This equals 760 (mm. Hg. air pressure) $\times 0.2096$ (the O_2 content of the air).

Power Density: The intensity of electromagnetic radiation power per unit area expressed as watts/cm^2.

Pulse Length: The duration of a pulsed laser flash. It may be measured in terms of millisecond (msec. = 10^{-3} sec.), microsecond (μsec. = 10^{-6} sec.), or nanosecond (nsec. = 10^{-9} sec.).

Pulsed Laser: A laser that delivers its energy in short pulses, as distinguished from a c.w. laser.

Q-Switched Laser (Q-Spoiled): A laser capable of extremely high peak powers for very short durations (pulse length of several nanoseconds).

Repetitive Pulse Laser: A pulsed laser with repeated pulsed output. The frequency of the pulses is termed pulsed reoccurrence frequency (P.R.F.). Repetitive pulse lasers have properties similar to a c.w. laser if the P.R.F. is very high.

Semi-Conductor or Junction Laser: A class of lasers which, at present, produce relatively low c.w. power outputs. This class of lasers may be "tuned" in wave lengths and are most efficient. (It is anticipated that higher power outputs will be made available through future developments.)

Specular or Regular Reflection: A mirror-like reflection.

Watt (W): A unit of power used in describing a c.w. laser output.

Watts per Square Centimeter (W/cm^2): A unit of power density used in measuring the amount of power per area of absorbing surface, or per area of a c.w. laser beam.

Glossary of Microwave Terms*

Absorption Loss: The loss of power in a transmission circuit that results either from coupling to a neighboring circuit or conductor or from dissipation or conversion of electrical energy into other forms.

Amplifier: A device for increasing the power associated with an input signal without appreciably altering its essential features. The output signal is controlled by the signal applied to the amplifier input, while the additional power is supplied by another source.

Amplitude: The amount of variation of an alternating quantity from its zero value. Instantaneous amplitude is the amplitude at any particular time, while peak amplitude is the maximum excursion on one side of zero, and peak-to-peak amplitude is the total excursion between peak values on both sides of zero.

ATR Tube: An antitransit-receive tube, which is a gas-filled, rf switching tube used to isolate the transmitter while a pulse is being received over a common antenna transmission line. The ATR tube is normally used in conjunction with a TR tube, between the TR tube and the transmitter, to present the proper impedance to the antenna transmission line when the transmitting tube is quiescent, so that all the received power will be coupled through the TR tube to the receiver.

Attenuation: Decrease in magnitude of current, voltage or power of a signal in transmission between points, usually expressed in db.

Attenuator, Flap: A device designed to introduce attenuation into a waveguide circuit by means of a resistive sheet moved into the guide.

Attenuator, Rotary Vane: A device designed to introduce attenuation into a waveguide circuit by means of varying the angular position of a resistive sheet in the guide.

Balanced Line: A line or circuit utilizing two identical conductors, each having the same electromagnetic characteristics with respect to other conductors and ground. A balanced line is preferred in circumstances where minimum noise and cross-talk is desired.

Balun: A device which provides coupling and matching between a balanced line and an unbalanced (i. e. coaxial) line.

Band: The continuous range of frequencies extending between two specified limiting frequencies.

Barretter: A metallic resistor with a positive temperature coefficient of resistivity used for rf detection and level measurements.

Bolometer: A device with a high temperature coefficient of resistivity, such as a barretter (positive), or thermistor (negative), which is used to sense rf power level.

BWO Tube: See Tube, Backward Wave.

Cavity: A metallic enclosure in certain types of tubes or circuits within which resonant fields may be excited at microwave frequencies.

Characteristic Impedance: The characteristic impedance of a uniform transmission line is the ratio of the applied voltage to the resultant current at the point where the voltage is applied, when the line is of infinite length. Characteristic impedance is commonly used to denote that impedance which may be connected to a transmission line or microwave device to provide an impedance-matched termination, i.e. a termination which will not reflect power, thus simulating a line of infinite length.

Choke Joint: A type of joint for connecting two sections of waveguide. It is so arranged that there is efficient energy transfer without the necessity of an electrical contact on the inside surfaces of the guide.

Circulator: A device having three or more ports with the characteristic that energy entering port 1 couples to port 2, entering port 2 couples to port 3, and entering the highest-numbered port couples to port 1. Such a device is, for example, very useful as an isolator if one of the ports is terminated. Thus, if port 3 is terminated and a BWO is connected to port 1, the BWO output appears at port 2, but any signal reflected by the load is absorbed in the termination on port 3 thus eliminating pulling. Circulators commonly use Faraday rotation to accomplish their non-reciprocal characteristics.

Coaxial Line: A TEM transmission line in which one conductor completely surrounds the other, the two being coaxial and separated by a continuous solid dielectric or dielectric spacers. Such a line is characterized by having no external field and no susceptibility to external fields from other sources.

Coupling Coefficient: In directional couplers, the ratio of the power entering the main arm to the power output obtained from the auxiliary arm.

Cutoff Frequency: The frequency at which the output of a device begins to attenuate. Specifically, it can be the band edge of a filter, or the lowest frequency at which lossless waveguide will propagate energy at a particular mode with little attenuation.

Crossed-Field Device: An electron device (such as a magnetron tube having a cylindrical cathode surrounded by an anode structure) in which electron current from the cathode is influenced by a magnetic field acting at right angles to the applied electric field. When electrons move away from the cathode, in a direction perpendicular to the magnetic field, this field imposes a force at right angles to the electron motion. The electrons then spiral into orbit around the cathode rather than moving collinearly with the electric field. Most of the electrons move gradually closer to the anode, losing potential energy which they contribute to the rf field as they interact with the anode slow-wave structure. The tube structure may be cylindrical or linear.

Crystal Detector (Square Law): A device whose output voltage is proportional to the square of its input voltage. Often used to measure relative rf power level or to present the wave envelope on an oscilloscope.

Decay Time: Generally defined as the time required for a voltage to decay to 1/e of its original value.

Decibel: The db is a unit of power ratio measurement. (Voltage can be used if impedance is constant.) The db is a ratio of gain (amplification) or loss (attenuation) in an electronic system. Expressed algebraically, it is:

$$DB = 10 \log_{10} \frac{P_2}{P_1} \quad \text{or} \quad 20 \log_{10} \frac{V_2}{V_1}$$

Decibel below one mw (dbm): The dbm or decibel/milliwatt is a power level with a db ratio referenced to 1 mw. A 0 dbm specification means the level is 1 milliwatt. 0 dbm = 1 mw, 10 dbm = 10 mw, -10 dbm = 0.1 mw, and so on.

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Decibel below one watt (dbw): The dbw or decibel/watt is a power level with a db ratio referenced to 1 watt. 0 dbw = 1 watt, -10 dbw = 100 mw, 10 dbw = 10 watts, etc.

Delay Line: See Wave Circuits, Slow.

Diodes:

> **PIN:** This diode is made by diffusing the semiconductor with P dopant from one side and N dopant from the opposite side with the processes so controlled as to leave a thin intrinsic region separating the two. (P dopant enhances the flow of holes and N dopant the flow of electrons.) The PIN diode has long enough storage time that at microwave frequencies, it cannot rectify. It appears, rather, as a variable resistor whose value is controlled by a dc bias current. It is therefore well suited for use as a variable microwave attenuator.
>
> **PN:** PN diodes have no intrinsic region and have a short storage time. They function as a normal diode rectifier into the high microwave regions. If the diode is dc biased so that the rf signal is small compared to the bias voltage, they cease to be rectifiers. Reverse bias causes the diode to appear as a small capacitor whereas forward bias causes it to appear as a resistor. Thus, it can be used as a reflective microwave switch. It can also be used as a variable reflective attenuator except for the operating region where the bias and rf voltages are comparable and rectification occurs.
>
> **Point Contact:** These diodes consist of a semiconductor with a very small wire (catwhisker) pressed against it. Such a diode has very low reactance and serves as a detector or mixer over most of the microwave range. At low power levels, it has a square law response.

Directional Coupler: A device consisting of two transmission lines coupled together in such a way that a wave traveling in one line (the main line) in one direction excites a wave in the other line (the auxiliary arm), ideally, in one direction only.

Directivity: Let P_2 be the power out of the auxiliary arm of a directional coupler with power P_1 into the main line input of the directional coupler, while the main line output and auxiliary arm are terminated with matched terminations. Let P_3 be the power out of the auxiliary arm with P_1 into the main line output, while the main line input and auxiliary arm are terminated with matched terminations. The directivity is the difference in db between the ratio of $\frac{P_2}{P_1}$ and $\frac{P_3}{P_1}$.

Duty Cycle: The fraction of time that a pulse signal is on, i. e. pulse duration in seconds times repetition rate in cps.

Faraday Rotation: A linearly polarized wave is equivalent to a combination of two circularly polarized components of equal amplitude and opposite rotational sense. Faraday rotation is the apparent rotation of the plane of polarization of such a linearly polarized wave as it propagates in a medium which exhibits a different propagation constant for the two component waves of opposite rotational sense (such as a ferrite material).

Field Intensity: The electrical force exerted by an electric field on a unit charge present therein. Normally expressed in volts per meter.

Frequency Pulling: A change of the source frequency caused by a change of the load impedance seen by the source.

Frequency Pushing: A change of the source frequency caused by a change in electron current flow within the source oscillator; e. g. the change in BWO beam current due to a change in the grid or anode voltage causes a change in frequency.

Frequency Stabilization: In reference to an oscillator, a means of eliminating or minimizing both long- and short-term instability or other inaccuracy in the output frequency. Normally achieved by sampling the oscillator output signal for comparison with an ultra-stable reference, and using the comparator to develop a frequency- or phase-controlling feedback signal to synchronize the oscillator output with the reference. Such systems are described as employing frequency-lock or phase-lock respectively. Phase-locked systems achieve better short term stability than frequency-locked systems.

Harmonic: A sinusoidal wave having a frequency that is an integral multiple of a fundamental frequency. For example, the second harmonic is a component of a complex signal whose frequency is twice that of the fundamental frequency of that signal.

Hybrid Circuit: A functional combination of integrated circuit and discrete (individual) components.

Hybrid Junction or Hybrid T: A component with four branches, which,when branches are properly terminated, has the property that energy can be transferred from any one branch into only two of the remaining three. In common usage this energy is equally divided between the two branches and the two outputs are in phase quadrature.

Incident Power or Signal: Power flowing to a load or using device from the signal source.

Insertion Loss or Gain: The loss or gain produced by adding (inserting) a device into a signal transmission path. Normally equivalent to the transmission loss or gain of the device measured between its input and output terminals. Insertion loss is commonly used to define the loss of a variable attenuator when set to zero.

Integrated Circuit: An electronic circuit or system fabricated by the vacuum deposition of both active and passive components in a single piece of manufactured crystalline material or ceramic.

Iris: In a waveguide, a conducting plate or plates, of thickness small compared to a wavelength, occupying a part of the cross section of the waveguide. When only a single mode can be supported, an iris acts substantially as a shunt admittance.

Isolator, Ferrite: A microwave device which allows rf energy to pass through in one direction with very little attenuation while rf energy flowing in the opposite direction is absorbed (attenuated).

Limiter: A device which, with input signal drive above a minimum level, limits the output amplitude to a predetermined value.

Maser (Microwave Amplification by Stimulated Emission of Radiation): A low noise, microwave amplifier utilizing controlled energy level changes in a medium to obtain signal amplification. Common media are gases (ammonia) and crystals (ruby).

Matched Termination: A termination producing no reflected wave at any transverse section of the transmission line. It is equal to the characteristic impedance, Z_o.

Microstrip: A microwave transmission component utilizing a single conductor supported above a ground plane. Also called stripline.

Microwaves: In general usage, microwaves refer to those radio-frequency wavelengths which are sufficiently short to exhibit some of the properties of light. Microwaves are usually used in point-to-point communications because they are easily concentrated into a beam.

Microwave Region: That portion of the electromagnetic spectrum lying between the far infra-red and conventional radio frequency portion. Commonly regarded as extending from 1 GHz (30 cm wavelength) to 300 GHz (1 mm wavelength). The region above 26 GHz is often referred to as the millimeter region.

Mismatch Loss: The loss in transmitted power expressed in db resulting from load mismatch, e.g. a VSWR of 2:1 results in a mismatch loss of 0.51 db. It is defined as $-10 \log_{10} (1 - |\rho|^2)$ where ρ is the reflection coefficient.

Modes: Used to denote field patterns which characterize the way in which electromagnetic waves propagate axially on a transmission line. There are two general types of modes: the TE modes in which the electric fields are everywhere transverse to the axis of the waveguide, and the TM modes in which the magnetic fields are everywhere transverse to the guide axis.

Noise Figure: A figure of merit defined as the ratio of the available signal-to-noise power at the input terminals of a device to the available signal-to-noise power at the output terminals, usually expressed in db.

Noise Power: The random power (noise) contained in a signal which tends to mask the desired intelligence in the signal. Noise power is present due to thermal agitation in resistances within a device, random motion of electric charges within a device, and thermal noise or background pickup at the device input.

Parametric Amplifier (MAVAR - Mixer Amplification by Variable Reactance): A microwave amplifier utilizing the non-linearity of a reactive element to obtain amplification with low noise figure.

Phase Shifter: A device for adjusting the phase of a particular field component at the output of the device relative to the phase of that field component at the input.

PIN Diode Attenuator: A two-port network composed of two or more PIN diodes controlled by a driver circuit. The diodes act as a small capacitance shunted by an electrically variable resistance at microwave frequencies, and can be varied in resistance over a range of about 2 - 10,000 ohms by controlling the bias current by means of the driver circuit. Multiple-diode units can be arranged in a network in which one or more diodes attenuate the microwave signal passing from input to output, and the other diodes maintain the input and output impedance at a near-constant level to match the transmission line. Some ALFRED PIN Diode Attenuators are designed to give substantial control range over many octaves of frequency while maintaining impedance matching at both ports.

PM Focusing: Focusing of the electron beam in a TWT or BWO tube by means of an axial magnetic field established by a single permanent magnet extending the full active length of the tube. The full-length permanent magnet is located outside the evacuated envelope with poles at each end of the tube.

Polarization: In electromagnetic waves, refers to the direction of the electric field vector. When the electric and/or magnetic fields are in a plane perpendicular to the direction of propagation in a transmission line the waves are said to be transverse. If transverse waves do not change in angular direction from instant to instant within this plane of polarization, they are said to be linearly polarized. Circular polarization is the resultant electric field produced by the combination of two equal-amplitude linearly polarized waves at right angles to each other and 90° out of phase. With circular polarization, the electric field vector at any point describes a circle in a plane perpendicular to the direction of propagation.

Power: The time rate of transferring or transforming energy. Electrically, power is expressed in watts, which is the product of applied voltage and resulting in-phase current. The difference between level and power is that power always designates a definite quantity while level expresses relative power and is normally measured in db.

Power, absolute: The power level expressed in watts or dbm, i.e. in absolute units.

Power, average: In the case of a sinusoid, this is the RMS value. In the case of pulses or square waves, it is the peak power multiplied by the duty cycle, i.e. the duty cycle of a square wave is 0.5, therefore, the average power is 0.5 times the peak power. Expressed in absolute power units.

Power, peak: The maximum power reached during a pulse. Expressed in absolute power units.

Power, relative: Power level referred to some other power level, usually expressed in db.

PPM Focusing: Focusing of the electron beam in a TWT or BWO tube by means of an axial magnetic field established by a series of small permanent magnets (periodic permanent magents) extending the full active length of the tube. The small permanent magnets are oriented axially along the tube, with adjacent magnets polarized in opposite directions. The small magnets are located outside the vacuum envelope and are separated by pole pieces which surround the envelope and carry to it the individual axial field contributions of the magnets. The polarization alternation results in cancellation of the external magnetic field.

Precision Connector: A coaxial connector designed to mate with another identical connector in such a way that electrical discontinuities in the transmission line are eliminated or minimized. These connectors are intended to combine the inherent advantages of coaxial devices (broadband performance, mechanical flexibility, low cost) with the electrical efficiencies (minimum contact resistance and VSWR) previously available only with waveguide. ALFRED equipment is available with Amphenol APC-7 precision connectors which are sexless, i. e. any connector will mate with all other connectors of the same type.

Propagation Constant: A transmission characteristic of a line which indicates the effect of the line on the wave being transmitted along the line. It is a complex quantity having a real term, the attenuation constant, and an imaginary term, the phase constant.

Pulse Repetition Rate: The average number of pulses per unit time in a pulse train.

Q-Factor: With regard to a resonant cavity, the ratio of energy stored to energy dissipated per cycle.

Rectangular Waveguide: A hollow tube of rectangular cross section normally having sides with a dimensional ratio of 2:1. With rectangular waveguides so proportioned, the dominant mode will have a free-space wavelength range between one and two times the larger cross-section dimension. Rectangular waveguide is normally usable only over less than octave ranges.

Reflected Power or Signal: Power flowing from the load or using device back to the signal source, due to impedance mismatch at the load or device input.

Reflection Coefficient: The vector ratio of the reflected voltage to the incident voltage at the same point. If the point of reflection is a pure resistance, the reflection coefficient is the numerical ratio of the incident voltage to the reflected voltage.

Reflectometer: A microwave system arranged to measure the incident and reflected powers and indicate their ratio.

Resonator, Cavity: A closed section of coaxial line or waveguide, completely enclosed by conducting walls, often made variable and used as a wavemeter.

Return Loss: The ratio of incident to reflected power expressed in db. It is defined as $-20 \log_{10} |\rho|$ where ρ is the reflection coefficient.

Rise Time: Generally construed to be the time required for a step function, pulse, or square wave to rise from 10 to 90 percent of its final amplitude.

RMS Amplitude (Root-Mean-Square Amplitude): The value of an alternating current or voltage that produces the same power dissipation in a certain resistance as dc current or voltage of the same value. The RMS (or effective) value of a periodic quantity is the square root of the average of the squares of the values of the quantity taken throughout one period. If the periodic quantity is a sine wave, its effective (RMS) value is 0.707 of its peak amplitude.

Sampler: A directional coupler which has a detector attached to the auxiliary arm to provide a video output sample proportional to the input power level. For applications in which the sampler is used to monitor power or drive a closed-loop source leveling system, a directional coupler having a flat coupling coefficient must be used.

Signal-to-Noise-Ratio: The ratio of the field intensity of a radio wave to the radio noise field intensity at the same point. It may also be considered as the ratio, at any point of a circuit, of signal power to total circuit-noise power.

Sliding Load: A length of transmission line containing a matched electrical load which can be positioned at a variable distance from the connector end.

Sliding Short: A length of transmission line containing an electrical short which can be positioned at a variable distance from the connector end.

Slotted Section: A length of transmission line having a nonradiating slot cut in the wall to admit a probe used for standing wave measurements.

Smith Diagram: A diagram developed to aid in the solution of transmission line and device impedance problems by permitting simple evaluation of impedance at any location or frequency.

Solid-State Oscillator: A semiconductor device packaged with an external circuit to provide rf output by utilizing the charge-handling properties of the semiconductor (instead of signal interaction with an electron beam flow through evacuated space as in an electron tube).

Spectrum Analyzer: An instrument which can determine and display the frequency components present in any signal or complex waveform, together with their relative amplitude, usually on an oscilloscope.

Stripline: See Microstrip.

Synchronization: See Frequency Stabilization.

Tangential Sensitivity: The absolute signal level in dbm required to produce an output signal which elevates the noise by an amount equal to the average noise level with no signal present.

Thermistor: A resistance element made of a semiconducting material which exhibits a high negative temperature coefficient of resistivity.

TR Tube: A transmit-receive tube, which is a gas-filled rf switching tube that enables a system to use the same antenna for both transmitting and receiving. The TR unit prevents the transmitted power from injuring the sensitive receiver. A TR unit normally consists of a cavity containing a discharge gap which completes the transmitter circuit to the antenna, and a coupling circuit which connects the received signal from the antenna to the receiver when the discharge gap is not fired, indicating that the transmitting tube is quiescent.

Transmission Line: Any structure used to guide the flow of electrical energy from one point to another. Most commonly used types are coaxial lines and rectangular waveguide (see definitions). Other types include parallel plate, stripline, ridged waveguide, and circular waveguide.

Transmission Loss or Gain: Refers to the relative change in power level of a signal transmitted from one point to another, such as within a circuit or between the input and output terminals of a device.

Tube, Backward Wave (BWO): A traveling-wave tube in which the electrons travel in a direction opposite to that in which the wave is propagated (microwave oscillator or narrowband amplifier).

Tube, Klystron: An electron tube in which the electrons are periodically bunched by electric fields formed by electrodes and cavities. It is used as an oscillator or amplifier for microwave signals.

Tube, Magnetron: An electron tube in which the electron flow from the cathode to the anode is influenced by the magnetic field applied perpendicular to the cathode-anode path, and by the field effects produced by the anode cavities. The electrons follow a spiraling path and reach the anode in bunches, producing output oscillations. The abbreviation VTM is used for voltage-tuned magnetrons.

Tube, Traveling-Wave (TWT): A broadband microwave tube which depends for its characteristics upon the interaction between the field of a wave propagated along an rf delay line structure and a beam of electrons traveling in near synchronism with the wave.

Tuning Screw: A screw or probe inserted into a transmission line (parallel to the E Field) to develop susceptance, the magnitude and sign of which is controlled by the depth of penetration of the screw.

Tunnel Diode: A PN diode to which a large amount of impurity has been added. It offers high-speed charge movement and a negative resistance region above a minimum level of applied voltage. It can be used as an oscillator or amplifier with suitable external circuits.

UHF: Ultra-high frequency, the band of frequencies between 300 and 3000 MHz.

Unbalanced Line: A line or circuit which is asymmetric with respect to ground and/or other conductors, usually having ground serve as one of the circuit conductors; e. g. a coaxial line.

VHF: Very high frequency, the band of frequencies between 30 and 300 MHz.

Varactor: A PN junction device in which the capacitance varies with applied voltage. It can be used as an oscillator or harmonic frequency multiplier with suitable external circuits. It is also used as a variable capacitor, e.g. for voltage control of oscillator frequency.

Velocity, Group: The velocity with which the envelope of an electromagnetic wave travels in a medium, usually identified with the velocity of energy propagation.

Velocity of Light: 300 meters per μsec in air, designated by the symbol C. The product of group and phase velocity in a medium always equals the velocity of light in that medium.

Velocity Modulation: Impressing a periodic variation in velocity on an electron beam, for example, by exposing the beam to a time-varying axial voltage.

Velocity, Phase: The velocity with which a point of constant phase is propagated in a progressive sinusoidal wave.

Voltage Standing Wave Radio (VSWR): The measured ratio of the field strength of a voltage maximum to that of an adjacent minimum along a transmission line. VSWR = $\frac{1+|\rho|}{1-|\rho|}$ where ρ is the reflection coefficient.

Wave Circuits, Slow: A microwave circuit designed to have a phase velocity considerably below the speed of light. The general application for such waves is in traveling-wave tubes. Commonly called a microwave delay line.

Wave, Transverse Electric (TE Wave): In a homogeneous isotropic medium, an electromagnetic wave in which the electric field vector is everywhere perpendicular to the direction of propagation. The dominant rectangular waveguide mode is TE_{10}.

Wave, Transverse Electromagnetic (TEM Wave): In a homogeneous isotropic medium, an electromagnetic wave in which both the electric and magnetic field vectors are everywhere perpendicular to the direction of propagation. This is the normal mode in coax, open wire, and stripline.

Wave, Transverse Magnetic (TM Wave): In a homogeneous isotropic medium, an electromagnetic wave in which the magnetic field vector is everywhere perpendicular to the direction of propagation. This mode is not widely used.

Wavelength: The distance between adjacent points of the same phase in a wave train. It corresponds to the distance traveled by the wave in one cycle.

Wavemeter, Absorption: A device containing a resonator which causes it to absorb maximum energy at its resonant frequency when loosely coupled to a source. It is used for measuring frequency.

Wavemeter, Transmission: A device which utilizes a cavity to transmit maximum power at resonance and thereby provide maximum deflection on a readout meter at the frequency of resonance.

YIG Device: A component using single-crystal Yttrium Iron Garnet (YIG) as a resonant structure which can be electronically tuned.

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